

Environmental Management in Design

*Lessons from Volvo and
Hewlett-Packard for the
Department of Defense*

Susan Resetar

Frank Camm

Jeffrey Drezner

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PREFACE

Weapon systems are major drivers of the Department of Defense's environmentally related activities. Consideration of these effects during early design offers a potentially significant payoff to military capability and overall environmental management activities. This report integrates information from case studies of Volvo and Hewlett-Packard with academic, policy, and trade literature to draw out lessons learned on best-in-class management processes that incorporate environmental concerns into new product design. It is intended for use by the Department of Defense to improve its environmental management practices during weapon system acquisition.

This activity is part of a larger study that examined four areas of importance to DoD: designing weapon systems to have improved military capability and cost-effective environmental performance; managing the industrial processes in central logistics activities; balancing environmental, military, and cost considerations in managing an installation; and managing remediation projects. Lessons from private industry leaders in these areas were examined for the Department of Defense.

This report may be of interest to defense acquisition managers, weapon system designers, as well as to product managers, design engineers, and environmental policymakers in both the public and private sectors.

The Office of the Deputy Under Secretary of Defense for Environmental Security sponsored this research. It was performed in the Acquisition and Technology Policy Center of RAND's National

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SUMMARY

A new approach to environmental management is rapidly evolving in a number of large, successful commercial firms. The Department of Defense (DoD) has adopted environmental management policies very similar to those found in these organizations. The Office of the Deputy Under Secretary of Defense for Environmental Security asked RAND to study how leading commercial firms had implemented their policies and suggest what DoD could do to improve its own implementation departmentwide. This report focuses on best commercial experience relevant to one key policy issue in defense environmental management—designing new weapon systems to have improved military capability and cost-effective environmental profiles over their lifetimes.¹

The Secretary of Defense has issued a comprehensive pollution prevention strategy that seeks to incorporate pollution prevention into all mission areas, including the life-cycle management of installations, the procurement of goods and services, and all phases of the acquisition process (Perry, 1994b). Because weapon systems can influence the pollution prevention activities in all three of these domains, they are important determinants of the department's overall environmental management activities and levels. Failure to anticipate and plan for potential environmental impacts can lead to expensive maintenance actions, disruption of training exercises, or

¹The study also addresses three other areas: environmental management relevant to central logistics, installation management, and cleanup. RAND's work on these areas is documented elsewhere.

delayed deployment of new systems. These problem can reduce mission capability or readiness or make them more costly to attain.

ANALYTIC APPROACH

This report is based on a review of the recent academic, policy, and trade literature and in-depth case studies of two firms with active and innovative programs in new product design. We used the literature to construct general descriptions of best practices in the commercial sector and to identify individual firms for more in-depth analysis.

Because the success of implementation depends heavily on the fine details of how a policy or practice fits in a particular organizational culture, understanding the organizational setting is important. Identifying why a particular practice worked in the original setting will facilitate understanding what DoD must consider when transferring this practice to its own setting. When working with information from the ongoing operations of commercial firms, it is important to remember that these firms evolve over time, often very rapidly. So the information we collected provides a transitional snapshot of each company. Faced with dynamic environments, these firms have moved on since we collected this information and continue to refine their approaches to environmental management.

This report reflects information from Hewlett-Packard and Volvo Car Corporation, augmented with information on other companies that was available in open literature.² These firms have reputations for innovative management practices and environmental leadership, maintain comprehensive design-for-environment activities relevant to DoD, and were willing to participate. Because they are not major defense contractors, their experience is more likely to bring new insights to DoD. In particular, Volvo takes a sophisticated approach to life-cycle assessments; has efforts under way to deal with potential European takeback legislation; which requires the original equipment manufacturer to take back products when their useful life

²The other firms studied in detail are to be determined for manufacturing processes analogous to central logistics, Disney and Proctor and Gamble for integrated facility management, and DuPont and Olin for remediation program management.

is over; and maintains a comprehensive approach to environmental management that is well documented in its annual environmental report. Hewlett-Packard is well-known for its application of total quality management (TQM) practices to all aspects of its business, including a comprehensive approach to environmental management that is well documented in its annual environmental report.

DESIGN-FOR-ENVIRONMENT: A DEFINITION

An estimated 70 to 80 percent of a product's life-cycle costs are determined during design. As a result, much of the literature on design-for-environment suggests that changes in a design can cost-effectively leverage environmental effects, upstream and downstream. Changes made during design also generally yield greater returns than product modifications made later. Moreover, investments made in advanced engineering, before design begins, provide relatively low-risk, low-cost opportunities to find solutions to environmental issues.

Design-for-environment, or environmentally conscious design, like other innovative environmental management practices, is a relatively new concept. Broadly defined, design-for-environment addresses the organizational, legal, and methodological aspects of incorporating environmental issues into design and general management processes. It is the process by which product life-cycle environmental analyses are performed, strategies and priorities are established, and improvement opportunities are identified and implemented. Some people treat design-for-environment and life-cycle assessment interchangeably. But life-cycle assessment is only one of many analytic techniques used to identify, understand, and evaluate environmental effects in the design-for-environment process. As we shall demonstrate, design-for-environment must be integrated with other management processes.

Private sector design-for-environment activities are driven primarily by a desire to:

- Seek cost-effective solutions to environmental concerns expressed through a variety of mechanisms that include regulations; product standards; waste management, treatment, and disposal costs; and local community interests.

- Satisfy markets that differentiate products with varying environmental attributes.

Other leading reasons cited in the literature include the desire (in order of importance) to match or exceed competitor actions, mitigate product liability risk, act in a socially responsible manner, comply with corporate policy, strive for sustainable development, meet regulations, and meet supplier requests. Companies have also learned that the knowledge and understanding required to perform design-for-environment puts them in a better position to engage policymaking and standards organizations.

Private sector firms are motivated to pursue design-for-environment for many reasons that correspond to DoD's interests in improved environmental management and weapon system acquisition processes. While not transferable one-to-one to DoD's, these motivations are analogous to DoD's desire to:

- Seek cost-effective solutions to weapon system life-cycle environmental issues that ensure military capability and mission readiness in peacetime as well as war.
- Ensure that operators' and maintainers' environmental management needs are addressed and that these personnel are adequately protected from environmental, health, and safety risks during operations, maintenance, and disposal.
- Invest in technologies and equipment consistent with future trends in regulatory policies.

ELEMENTS OF IMPLEMENTATION

Although motivations may be similar among private sector companies, implementation practices vary. There is no "silver bullet" to design-for-environment implementation, primarily because implementation requires integrating design-for-environment processes and goals with core corporate strategies, values, and processes. This deceptively simple statement means that companies or organizations cannot blindly adopt "best-practices techniques." Relating environmental issues to core values, and integrating them into established management processes, requires insight into the orga-

nizational culture and norms. It also requires a solid understanding of the business issues, such as customer wants and needs, markets, competitive position, and technological aims. For DoD this may be translated into a solid understanding of operator and maintainer wants and needs, constraints and requirements on future operating environments, and alternative technological approaches.

Implementation requires a comprehensive "package" of activities that address different management issues and reinforce one another. It is imperative that each "activity set" within the "package" be implemented in a way that fits into established practices and other business processes and balances the competing demands or aims of the organization.

One of the overarching lessons learned from the case studies of Volvo and Hewlett-Packard is that design-for-environment *relies on the individual decisionmaker*. The ultimate outcome of any design-for-environment process is a result of the accumulation of many small and large trade-offs made by these individuals. Therefore, successful design-for-environment practices will emphasize improving the individuals' awareness and knowledge of environmental issues as they relate to the decisions in their control. It also involves empowering individuals to incorporate environmental decisionmaking in their processes.

Another overarching lesson is that design-for-environment should fit within existing processes. Design engineers, product managers, and business managers in general have many demands on their time. Since environmental issues are only one of a multitude of categories that must be considered in design, activities that minimize the burden on these participants are more likely to succeed. For example, Volvo engineers specifically require that the life-cycle assessment tool, the Environmental Priorities Strategies, calculate a single number for ease of use.

In addition, the design-for-environment processes should reflect corporate culture. A strong rationale for design-for-environment, specific to the organization's activities, should be developed and socialized appropriately throughout.

Finally, design-for-environment implementation is much like other organizational change processes. Companies seek this change by

beginning with small, experimental activities. These are relatively low-risk yet provide useful information on what works, what doesn't, and what new or additional pieces of information might be necessary. However, because environmental issues touch on the individuals' core values and ethics and because they tend to be value-laden and uncertain, integrating environmental issues with business decisionmaking can be more difficult. To motivate behavioral change most effectively, the learning process must address what is called the "affective domain," or an individual's value system and attitudes toward the subject matter. To ensure that this occurs, environmental education should accompany new skills training. The management change process requires continuous leadership as well as patience and time. At the time of the interviews, Volvo and Hewlett-Packard had been developing their programs for approximately six years and both recognize that the programs are still in their formative stage.

In addition to these overarching themes, five sets of activities were common to design-for-environment implementation:

Vision and strategy. Senior management clearly articulates the purpose and role for environmental management in such a way that divisions or business units can readily operationalize the guidance. The environmental policy is used to articulate a clear vision for treatment of environmental issues. The policy can be used to communicate the organization's intent both internally and externally. Strategies are then developed based on the vision in the policy statement and the market forces (including regulatory forces) facing the product lines. The strategy provides focus, and in some cases priorities, to design and other environmental decisions. In some cases, it is also used to provide investment flexibility.

Organizational structures. Organizational structures are in place to address environmental issues strategically and proactively, establish goals and communicate progress toward these goals, and create and share new knowledge about and methodologies for design-for-environment. Organizational levels are linked with clear access to senior management. The organizational elements of a design-for-environment program are perhaps the most challenging and yet are the most important to address early. In many instances, it is easier to focus on such logical tools as life-cycle assessments than to focus on

the complexities of the organizational and psychological barriers to change. However, without the organizational mechanisms to both drive and implement the findings of these analyses, no progress will take place.³

Both Hewlett-Packard and Volvo have organizational structures in place to assist the flow of information and to make decisions—both up and down the management chain as well as across different organizations within the company. Generally, a corporate-level executive board is in place to develop or approve environmental policies. It serves as a clear organizational link between design-for-environment and strategic business activities. This link also ensures high-level management support and attention when necessary. Champions are identified at the product-line and business-unit levels to facilitate the incorporation of environmental issues into design processes and design decisions and to help move the program forward. Employees with an understanding of market forces and the challenges of product design are generally selected for this role. These champions at the product-line level are linked to environmental management and other champions. The parallel structure facilitates the flow of information to guide decisions, and the integration of environmental staff with functional experts helps build awareness and new competencies where necessary.

Management metrics and goals. Metrics, aligned with the vision and strategy, are used to focus attention and guide design decisions and investments. Specific goals for the metrics are developed by the responsible business units or product development teams and are used to drive action and improvement. The goals are built through intensive networking among the environmental group experts and the other functional units. The environmental experts motivate line organizations to consider environmental effects, provide expertise on environmental issues, relate actions of the functional units to specific environmental measures and goals, and create visibility for these goals and build political support for their realization throughout the company and among all managers. This process relies heav-

³One company contacted had spent more than five years developing a sophisticated life-cycle assessment model in its development center. However, life-cycle analyses had not been performed in product designs, in part because the model had no organizational home in the product divisions.

ily on raising individual awareness and analytic skills with respect to environmental performance.

In most cases, interdependencies exist between the metrics; a framework to integrate these metrics, or a prioritization scheme, makes trade-offs easier.⁴ Finally, mechanisms are in place to track or assess progress toward these goals and to seek continuous improvement. Usually this is performed through formal reviews or audits with some corporate-level involvement.

Supplier involvement. True systems-oriented design approaches will consider supplier contributions to product and process goals. Many companies include suppliers directly in their life-cycle analyses that are used to develop a strategic focus for management attention, further analyses, and investments. However, suppliers are actually involved in design-for-environment processes to varying degrees. The most common and direct mechanism companies have to influence suppliers is through the procurement process—through environmental criteria in the overall supplier selection criteria or through environmental specifications. Generally, companies look for suppliers to have compatible environmental policies with management practices to implement them. Often suppliers will be required to eliminate certain materials or chemicals from their products. Several companies note that it is much more effective to work cooperatively with suppliers to solve problems than it is to use product specifications to dictate requirements.

Training and tool development. Training, analysis methodologies, data and information, and other design aids serve two primary purposes. First, they increase the awareness of decisionmakers throughout the organization who affect a product's ultimate environmental profile. Second, they facilitate and guide proper decisionmaking.

Many types of analytic tools and design methodologies are important to any design-for-environment process. They can be grouped into

⁴Volvo uses its long-established priorities and its life-cycle assessment tool, called the Environmental Priorities Strategies (EPS), to frame its decisionmaking. This benefit of structured analysis was also reflected in a survey of 34 companies in the chemical, electronics, and consumer products industries. Companies reported that the overwhelming benefit of life-cycle assessments was that they help establish priorities and enable decisionmaking (Gloria et al., 1995, p. 45).

three broad categories: engineering and design tools, accounting methods and tools, and program or process control techniques. A particular analytic tool may be more applicable to a given design phase, and more than likely multiple tools or methodologies will need to be developed for a complete program. Because environmental issues are one set of many that influence the design process, analytic techniques that consider environmental issues must be incorporated into existing product-realization processes in a way that does not add time or complexity.

Just as important as *which* analytic technique is *how* the analytic tool is developed and integrated into design processes. It is more important to get the design-for-environment process started than to have analytic tools that are precise to the *n*th degree. A fledgling design-for-environment program can be easily overburdened with extensive data requirements. Successful development and implementation of new analytic tools will also involve users early.

RECOMMENDATIONS FOR THE DEPARTMENT OF DEFENSE

DoD's Environmental Security Strategic Plan seeks to incorporate pollution prevention into the acquisition process. To do this, DoD has already undertaken several initiatives in recent years. Our analysis suggests that DoD could advance the implementation of its strategic plan in a number of specific ways.

Vision and strategy. DoD's environmental security community could engage the other functional organizations—others within acquisition and technology, installations management, and logistics and other operational organizations within OSD and the armed services—to update DoD's environmental policy. The engagement is at least as important as the plan itself. As Volvo's corporate managers discovered when they did this, such a cross-functional discussion would give the operators in DoD a greater sense of ownership with respect to environmental policy as well as a much richer understanding and awareness of the policy's intent and nuances.

By developing environmental strategies by weapon system type, using the revised environmental policy and issues raised in its devel-

opment, DoD could help individual weapon system program offices (SPOs) benefit from prior DoD experience. Such strategies would study previous acquisition programs to build templates of environmental effects and use them to organize information on key environmental issues, priorities, and cost drivers by weapon system type.

Organizational. Each SPO and contractor design team should have an environmental product design steward to champion environmental management within the program and to serve as a link to the rest of DoD on such issues. The Environmental Security staff should meet with these individuals to discuss the environmental issues of the program, metrics, technology needs, contractor issues, information needs, etc. This will help disseminate information and catalyze action. DoD should link designers directly to the Joint Group on Acquisition Pollution Prevention (JG-APP) to expose them to the way their customers—operators and maintainers—view life-cycle costs and environmental impacts. Once a year, DoD should give the Defense Acquisition Board (DAB) and the JG-APP a prioritized overview of the issues facing environmental stewards so that senior DoD leaders can refine DoD's relevant strategies and investment priorities and organizational or other barriers to progress.

Management metrics and goals. Appropriate product stewards and environmental security staff should develop a generic list of environmental metrics by weapon system type and link these to traditional weapon system acquisition program and system performance metrics—those reported in the Selected Acquisition Reports (SARs), DAB reviews, etc. For example, they could relate environmental issues of strategic importance to measures of fuel efficiency, system reliability and maintainability, system service life, and cost. As difficult as this is, it helps individual decisionmakers and designers understand how their decisions influence environmental management. They could also develop new measures for the significant environmental issues that may not relate to traditional measures. For each program, the program manager, the program office, and the contractor environmental stewards would be required to select the metrics that make the most sense and establish goals that improve on those for previous systems of the same type or class. DoD should emulate Volvo's efforts to apprise goal-setters of the organization's operational priorities by linking this goal-setting activity to the JG-APP.

The stewards and environmental security staff should track progress toward these goals. DoD should augment the current program review process with structured periodic environmental audits to ensure that programs adequately implement DoD's environmental policy and pursue the goals set. The Deputy Under Secretary of Defense for Environmental Security and the Under Secretary for Acquisition and Technology should receive the results of these audits.

Suppliers. Private sector companies have been clear and direct in their environmental requirements for suppliers, even when a buyer's position is not as dominant as DoD's position. DoD's suppliers will give environmental performance as much importance as DoD gives it in the priorities it sets with its suppliers. Identifying environmental stewards within both organizations will improve awareness of environmental issues and aid joint problem-solving. Shared program environmental metrics should help focus management attention and supporting analyses.

Training and analytic tools. Commercial experience verifies what DoD already knows—that effective training is critical to the broad implementation of proactive environmental management. Without detailed information on DoD's extensive training program, which would take us beyond the scope of this study, we cannot suggest how the program might be improved.

Extensive commercial experience demonstrates that analysis tools are useless if the organizations and processes are not in place to use the information that these tools generate. For example, Volvo's management is very involved in the development of the Environmental Priorities Strategies life-cycle analysis system. It uses the system, even though Volvo knows its outputs could be improved and refined. Because these tools must support real-time decision-making and incorporate detailed knowledge of systems design practices, environmental stewards and key functional experts from the SPO and defense contractors should participate in their development and interim testing. These techniques can begin simply and grow in sophistication as experience with them validates their usefulness.

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ABBREVIATIONS

AB Volvo	Volvo Corporation, Volvo Group
AFV	Armored fighting vehicle
BRAC	Base Realignment and Closure
BS 7750	British Standard 7750 (Environmental management systems)
CAD	Computer-aided design
CFC	Chlorofluorocarbon
DAB	Defense Acquisition Board
Dem/Val	Demonstration and Validation (phase)
DFE	Design-for-environment
DoD	Department of Defense
DSB	Defense Science Board
DSMC	Defense Systems Management College
DUSD(ES)	Deputy Under Secretary of Defense for Environmental Security
ECU	European Currency Unit
EH&S	Environment, Health, and Safety
ELU	Environmental Load Unit

EMAS	Eco-Management and Auditing Scheme
EMD	Engineering and Manufacturing Development (phase)
EPS	Environmental Priorities Strategies
ISO 9000	International Standardization Organization Quality System Standard
ISO 14000	ISO Environmental Management Standard
JG-APP	Joint Group on Acquisition Pollution Prevention
LCA	Life-cycle assessment
MOTIV	Environment and Toxicology at Volvo (translation from Swedish)
NGO	Nongovernmental organization
ODS	Ozone-depleting substances
OUSD	Office of the Under Secretary of Defense
PRP	Primary responsible party
SAR	Selected Acquisition Report
SETAC	Society of Environmental Toxicology and Chemistry
SKr	Swedish Kronor (monetary unit)
SPO	System Program Office
TQM	Total quality management
TQRDC-E	Technology, quality, responsiveness, delivery, cost, and environment
VCC	Volvo Car Corporation
VEMS	Volvo environmental management system
VOC	Volatile organic compound

Chapter One

INTRODUCTION

BACKGROUND

Just as the Cold War drew to a close, spending on environmental activities inside the Department of Defense (DoD) increased, particularly those expenses for remediating previous damage done by the department.¹ At the same time, increasingly tight environmental regulations constrained training and vessel mobility in DoD, potentially limiting military readiness. These trends brought environmental management into sharp focus in DoD. Was DoD making appropriate trade-offs among its military mission, environmental obligations, and constraints on its budget and other resources? Did opportunities exist to increase military performance without compromising environmental obligations or resource constraints?

During the 1980s and early 1990s, many U.S. firms found themselves in a similar situation. Even as their environmental obligations rose because of increasingly demanding regulations and threats of liability, increasingly effective global competition squeezed the firms' profit margins, forcing them to think about environmental management in a different way. A 1995 Defense Science Board (DSB) study recognized this parallel. It observed that:

Almost all premier private sector firms are providing environmental leadership. They are finding opportunities for cost savings through

¹Environmental expenditures from DSB, 1995, p. 9; DoD expenditures from U.S. Bureau of the Census, 1996, Table 517.

prudent environmental management, technology investments, and pollution prevention. They are also involving local and state stakeholders in their decisions. This proactive management approach is not pursued for altruistic reasons. The management [decision-makers] of these companies are convinced that they can reduce environmental costs in the long run, have greater flexibility in their operations and, hence, gain competitive advantages through such an approach.

The Task Force believes that the Department faces a similar set of decisions. If DoD takes a proactive leadership position—working with stakeholders, pursuing new technology and pollution prevention, leveraging its buying power, and pursuing the significant risks first—it will be in a much stronger position to assure U.S. national security interests. . . . It will be cheaper in the long run to meet its requirements in a proactive fashion than to be forced do so through protracted regulatory proceedings at the state and local levels. (DSB, 1995, p. ES-1.)

The Office of the Deputy Under Secretary of Defense for Environmental Security asked RAND to study the environmental management practices of commercial firms recognized as having the best practices of this kind in the country. Such practices should provide lessons that DoD could use to improve its own environmental management practices. This report is one product of the study that resulted from this request.²

ANALYTIC APPROACH

RAND first reviewed DoD's environmental management program by reading high-level DoD documents, interviewing environmental officials in the armed services, and visiting several representative bases. This review revealed two things.

First, DoD's high-level environmental management policy already reflected many of the practices that were proving successful in commercial firms. DoD's primary challenge was less one of knowing what to do than one of understanding how to implement this policy in a very large organization. Hence, the information DoD needed

²The others are forthcoming.

most from the commercial sector was how proactive firms had implemented the key elements of their environmental management programs.

Second, the review also revealed that among the many activities DoD pursues, four are particularly important to environmental management within the department. These four areas are:

- Designing new major weapon systems to have improved military capability and cost-effective environmental performance levels over their lifetimes.
- Managing the industrial processes in central logistics activities to balance military, environmental, and cost constraints appropriately in the support of existing weapon systems.
- Managing the many, diverse, environmentally relevant activities on installations in an integrated way to comply with current regulations and prevent future pollution cost-effectively.
- Managing the programs responsible for remediating waste disposal sites on active bases, bases being closed through Base Realignment and Closure (BRAC) reviews, and other sites where DoD is a primary responsible party (PRP).

This report focuses on the first area—designing new weapon systems to have improved military capability or mission readiness and cost-effective environmental profiles. It is based on an in-depth review of recent academic, policy, and trade literature. Proactive environmental management is not as prevalent among commercial firms as the DSB study suggests (see, for example, “Green Machine,” 1995, pp. 17–18; Greeno, 1996, pp. 5–15; Nagel, 1994, pp. 243–248), but the best firms are developing and implementing innovative practices. Like DoD, they find that implementation is more challenging than policy development.

We chose two firms at which we could study the implementation of environmental management during new product design. Because the success of implementation depends heavily on the fine details of how a policy or practice fits in a particular organizational culture, understanding the organizational setting is important. Identifying why a particular practice worked in the original setting will facilitate understanding factors that DoD must consider when transferring

this practice to its own setting. However, the case study approach is not without limitations. One noted by both companies selected for this report is that a case study represents a snapshot of an organization. Both companies have noted that their organizations are quite fluid and undergo continuous change. The adaptive nature of leading commercial companies is one of the observations of this study.

This report reflects information from Hewlett-Packard and Volvo Car Corporation, augmented with information on other companies that was available in open literature.³

Volvo and Hewlett-Packard were selected from a list of about a dozen firms, using the following criteria: reputation for environmental leadership, comprehensiveness of design-for-environment activities, applicability to DoD, innovative management practices, and willingness to participate. Companies that did a large portion of their business with the department were not considered, in order to view business from a different perspective—they might reflect the practices of such a large customer. Because weapon systems are so diverse and complex, the candidate companies excluded many of the active companies that create consumer products—or those whose products require relatively little design and systems integration, such as Georgia-Pacific, Interface Flooring Systems, and Proctor and Gamble. Companies in the automobile and electronic systems sectors were selected to approximate the complexity of weapon systems' (or at least weapon system components') design and system integration.

The selection of Volvo and Hewlett-Packard was based on an informal survey of the academic and industrial experts in the field of environmental management in design and a cursory review of the environmental reports of the candidate companies. Volvo was selected over other automakers in part because it had been identified as having a sophisticated approach to life-cycle assessments. Its early experience with European activities in anticipation of takeback legislation and the comprehensive treatment of environmental issues in its annual environmental report were two other factors contributing

³The other firms studied in detail are to be determined for manufacturing processes, Disney and Proctor and Gamble for integrated facility management, and DuPont and Olin for remediation program management.

to its selection. Hewlett-Packard was selected in part because it is a nondefense electronics company known for its use of total quality management (TQM) practices and the comprehensive treatment of environmental issues in its environmental report.

REPORT ROADMAP

As noted above, this report focuses on the management of environmental issues during weapon systems acquisition. Chapter Two provides an overview of weapon systems acquisition—summary characteristics of weapons systems, the acquisition process, and weapon system environmental issues. Environmental management activities that seek to influence this process must do so in the context of the primary purpose and function of a weapon system. Chapter Three describes why private sector companies are introducing environmental issues in design processes and offers a definition of such activities, which is often referred to as design-for-environment. Chapter Four synthesizes information on design-for-environment practices in the case study firms—Volvo and Hewlett-Packard—with additional information from the academic and management literatures. These lessons are applied to DoD in Chapter Five, which presents conclusions and recommendations. The detailed case studies of Volvo and Hewlett-Packard are presented in Appendixes A and B, respectively.

Chapter Two

ENVIRONMENTAL ISSUES IN WEAPON SYSTEMS ACQUISITION

Pollution prevention is a stated goal of the Department of Defense, and several years ago the Secretary of Defense issued a comprehensive pollution prevention strategy. This strategy sought to incorporate pollution prevention into all mission areas, including the life-cycle management of installations, the procurement of goods and services, and all phases of the acquisition process (Perry, 1994b). Moreover, a widely cited Department of Defense Inspector General statistic states that 80 percent of the department's hazardous material use, broadly defined, is driven by weapon systems.¹ Each weapon system life-cycle phase, from testing to manufacturing to operating to maintaining to disposing of these systems impacts the environment in some fashion. Weapon systems can influence the pollution prevention activities in all three of the domains identified in the pollution prevention strategy and therefore are important determinants of the department's overall environmental management activities and levels.

The specific environmental impacts of any given weapon system will determine which environmental activities must be performed and what investments must be made. These impacts are driven by weapon system characteristics determined primarily during the design process. By considering these issues and impacts in the design phase, serious or costly actions and investments could potentially be avoided, or at least be mitigated. Failure to anticipate and

¹DoD Inspector General, as cited by DSB, 1995, p. 42

plan for potential environmental impacts can lead to more costly or reduced military capability through a number of channels. It can lead to expensive maintenance actions, disruption of training exercises, or delayed deployment of new systems.

Besides affecting the department writ large during testing, operations, maintenance, and disposal, weapon system characteristics as they relate to environmental issues can affect execution of the acquisition program itself. Seventy percent of the 118 programs responding to a Defense Systems Management College (DSMC) survey reported that environmental issues caused an impact on their program, and 63 percent of these programs stated that their programs were affected in two or more ways. Most of the effects were detrimental; reports cited increased cost (76 mentions), followed by schedule delays (38), degraded system performance (10), and inability to meet system requirements (6) as the most common (Noble, 1995, Table 12-3, unnumbered pages). Despite these effects, detailed information on the environmental portion of weapon systems costs is difficult to obtain. These activities are most often included in overhead and therefore are not reported separately. One Aerospace Industries Association estimate suggests that between 8 percent and 30 percent of a weapon system's overall life-cycle cost stems from environmental, health, and safety issues.² Clearly, there are opportunities to improve weapon system life-cycle cost-effectiveness and program execution through design-for-environment, given these numbers.

Because DoD procures such a diverse set of weapon systems, the specific life-cycle phase and environmental impacts will vary from system to system.³ For example, the Navy's New Attack Submarine Program Office staff focused its attention on hazardous material use, solid waste generation and disposal, ozone depleting substance use, submarine discharges, natural habitat disruption, and submarine dismantling and disposal, among others in its environmental analyses (New Attack Submarine Program Office, 1997). For com-

²DUSD(ES) meeting with the Aerospace Industries Association on December 17, 1996, cited in Advanced Amphibious Assault Vehicle Program Office submission to the Secretary of Defense Environmental Security Awards for Pollution Prevention in Weapon System Acquisition, April 1997, p. 4.

³The different management priorities of the armed services may also cause variation.

parison, the Army's Bradley Fighting Vehicle Program Office staff focused on ozone-depleting substance use, cadmium dispersion, hazardous materials use, and volatile organic compounds in its analyses (Bradley Fighting Vehicle System Acquisition Team, 1997). Specific environmental issues of concern to weapon system program offices were identified in the DSMC survey of 118 program offices. Environmental concerns include (in order of number of mentions): ozone-depleting substances (103 mentions), toxics (71), volatile organic compounds (59), noise (53), petroleum products (51), heavy metals (36), endangered species (36), radioactive materials (26), historical or cultural site preservation (23), respirable fibers (22), and, to a lesser extent, electromagnetic effects, thermal waste, water contamination, and chemical agent resistance, among others.⁴

In summary, the Department of Defense seeks to emphasize pollution prevention in the future and new weapon systems acquisition offers high-leverage opportunities. Examples and studies have shown that weapon systems affect environmental management activities and military capability or mission readiness in innumerable ways. Failure to anticipate these impacts can increase life-cycle costs and reduce capability. Yet, the department faces many challenges in implementing pollution prevention, in part because the environmental impacts are so diverse.

DESIGN IMPLEMENTATION MUST CONSIDER WEAPON SYSTEMS DIVERSITY AND ACQUISITION REFORM OBJECTIVES

Weapon systems vary in terms of technical complexity, size, life-span, cost, and environmental issues. Table 1.1 presents some illustrative information for various weapon system categories. Note that these systems can take a long time to develop, reflecting their technical complexity and high value. These systems are also long-lived; most are expected to be operational for 30 to 40 years. In addition, many systems will experience several major modifications through-

⁴The increase in cost could be a mixture of acquisition and weapon system life-cycle costs, because the survey instrument used for this report did not specify a cost category. Limited information available in the report suggests that most interviewees interpreted cost as acquisition cost (Noble, 1995, Table 12-2, unnumbered pages).

out their lives. Procurement quantities are generally quite small but not necessarily so. Given these characteristics, the operations or use phase in a weapon system's life-cycle, including maintenance and repair, often dominates the environmental impacts and any design changes or investments that reduce environmental effects during this phase will be compounded over many years. Major modifications may offer additional opportunities to improve the cost-effectiveness of the weapon system's life-cycle environmental issues. However, technical solutions may be restricted by the demanding system and subsystem performance requirements.

The diversity of systems acquired by the Department of Defense means that any overarching program to consider environmental issues during weapon system design must be focused enough to drive action but flexible enough to accommodate a wide range of environmental considerations, cost structures, and improvement opportunities. In light of such system diversity and variability, limited environmental resources will necessitate developing strategic approaches to improving future systems. Management processes to transfer knowledge gained through analysis and operational experience from one weapon system generation to the next must be established. Moreover, because the operations phase is often so dominant, a design-for-environment program should emphasize incorporating input from the operators and the maintenance personnel into future strategies and designs.

Design-for-environment policies and processes also must be consistent with the goals of acquisition reform that seek to improve the management of the acquisition process. The weapon systems' design and development process is a very complex and uncertain one that involves multiple actors and decisionmakers, competing program objectives, long development times, multiple design objectives, and complex system integration, among others. Added to these challenges, the department is facing severe budgetary pressures. As a result, recent acquisition program guidance has emphasized more rapid modernization cycles that have a lower cost of ownership (Gansler, 1998a). To accomplish this, such practices as cost as an independent variable, use of commercial products and practices, use of flexible manufacturing, emphasis on modifications to existing systems, and modularity to extend weapon system lifetimes have been identified. Efforts to streamline the acquisition process

Table 1.1
Illustrative Weapon System Characteristics

System Category	System Life (years)	Time Between Major Modifications (years)	Avg. Procurement Quantity	Avg. Procurement Unit Cost (TY\$)	Design Time (DemVal+EMD) (years)
Aircraft					
Fighters	30	10	100	50M	10-15
Strategic	40	10-20	30	200M	7
Helicopters	30	10	100	10-20M	10
Missiles					
Tactical	10-20	7-10	1,000+	300K-1M	7-10
Strategic	30	10	20	N/A	10-15
Vehicles					
Tanks	30	7	240	4-5M	5-7
AFVs	30	10	240	1-2M	5-7
Trucks	30	15	1,000+	50-300K	5
Ships					
Surface	30-40	N/A	6-8	800M-3B	7
Carriers	50		1	5B	4-5
Submarines	30-40	10	1-2	1B-1.5B	10

SOURCES: Dan Norton, working notes, RAND, April 1997; Giles Smith, working notes, RAND, April 1997.

also include elimination of military specifications and standards and lengthy procedural instructions and movement toward commercial standards and practices. Because the modernization budget is approximately one-third of the entire budget, while operations and maintenance accounts are two-thirds,⁵ expectations are that acquisition reform will begin to emphasize operations and support areas to improve the cost-effectiveness of future weapon systems in the near future (Perry, 1994a; Kaminski, 1995a, b).

As we shall see in the subsequent discussion, many design-for-environment practices are consistent with such goals of acquisition reform as reduced life-cycle cost, system modularity, extended weapon system lifetimes, and use of commercial products and processes. For example, use of commercial products would improve the department's access to technological improvements in traditional performance areas as well as in environmental areas. This would expand and improve the department's technological base, saving time and money. For example, in the past DoD was unable to employ a new nontoxic soldering flux based on citric acid developed by Hughes until military specifications were rewritten (Goodman, 1994, p. 189).⁶

The department addresses environmental issues during design in numerous ways—through exchange in technical integrated product teams, program manager training, acquisition program guidance, the Joint Group on Acquisition Pollution Prevention (JG-APP) activities, and the development of simulation and modeling tools. The insights contained in the remainder of this report are intended to further develop these activities.

⁵The total obligational authority for fiscal years 1998 and 1999 are \$252 billion and \$257 billion, respectively, of which \$78.5 billion and \$85.8 billion are modernization accounts (RDT&E and Procurement). (DoD Comptroller, 1997.)

⁶The JG-APP is addressing outdated specifications.

WHAT IS DESIGN-FOR-ENVIRONMENT?

One method for practicing pollution prevention is to consider environmental issues in the early design stages of new weapon systems. As we will show, these practices are also consistent with standard management practices, such as TQM.

WHY DESIGN?

An estimated 70 percent to 80 percent of product life-cycle costs are determined during design (Office of Technical Assessment, 1992; Kainz Moeser, and Simpson, 1995). As a result, much of the literature on design-for-environment suggests that changes in the design can cost-effectively leverage environmental effects—both upstream and downstream. Changes during design also generally yield greater returns than product modifications made later. Moreover, investments made in advanced engineering, before design begins, provide relatively low-risk, low-cost opportunities to find solutions to environmental issues.

Hewlett-Packard, Volvo, and other companies have determined that, by taking control of product and process design, they can identify and invest in the most cost-effective technologies to achieve desired environmental performance levels. They also seek to engage the creativity of their design staffs to meet customer expectations and improve satisfaction (Fräjdin Hellqvist, 1996b; Korpalski, 1997; Bast, 1997a). Specifically private sector activities are driven primarily by a desire to:

- Seek cost-effective solutions to environmental concerns expressed through a variety of mechanisms that include regulations; product standards; waste management, treatment, and disposal costs; and local community interests.
- Satisfy markets that differentiate products with varying environmental attributes.

Other leading reasons cited in the literature for design-for-environment implementation by private sector companies include the desire to (in order of importance): match or exceed competitor actions, mitigate product liability risk, act in a socially responsible manner, comply with corporate policy, strive for sustainable development, meet regulations, and meet supplier requests.¹

The literature suggests that companies seek to gain greater strategic control of their products and to be better positioned to consider the trade-offs in cost and environmental performance to meet both internal and external environmental goals and requirements. They achieve this control by increasing their understanding of how design decisions affect the environmental profile of products throughout their life-cycle. Some have suggested that these actions improve competitive advantage—that companies can find many solutions to both economic and environmental objectives by treating environmental issues in corporate strategy, which in turn leads to better resource efficiencies and an improved ability to anticipate and meet emerging markets and regulations (Porter and van der Linde, 1995, pp. 120–134).²

Companies have also learned that the knowledge and understanding required to perform design-for-environment puts them in a better position to engage policymaking and standards organizations proactively. For example, Hewlett-Packard has put forward guidelines to policymakers, Volvo has used its knowledge to respond to proposed recycling legislation, and Xerox actively seeks improvement in

¹Based on a survey of 16 companies, in nine major industry groups, that have formal design-for-environment processes (Lenox, Jordan, and Ehrenfeld, 1996, p. 27).

²Others suggest that incorporating environmental issues into business management is not entirely straightforward, primarily because it increases the number of issues that management must consider, adding complexity to the decisionmaking process (Walley and Whitehead, 1994, pp. 46–52).

recycling infrastructures and product standards. By anticipating future regulations and market demands while striving for continuous improvement, companies can mitigate the uncertainty associated with regulatory change on the margin and are better equipped to negotiate on proposed future regulation. According to one design-for-environment expert, risk reduction is a primary motivation for these practices.³

The benefits of design-for-environment also extend beyond the individual company or organization. Broader than design alone, such concepts as chain management (also referred to as product stewardship or extended product responsibility) are fast growing as a mechanism by which environmental policymakers see potential for reducing the environmental footprint of products and services. By focusing on *systems of products*, rather than *facilities*, policymakers seek improved environmental outcomes at lower economic cost.⁴ Policies that are product-oriented rather than facility-oriented can potentially couple environmental and economic issues more closely.

Conceptually, the product system is the most basic linkage between the ecological and the social systems. It allows for a more comprehensive analysis and evaluation of the resources and environmental consequences involved in manufacturing of products. The patterns of demand and consumption of the social system are intimately linked to the ecological systems. The ecological system is the donor and acceptor of the resources and wastes, respectively, of the other two systems. (Galeano, 1997, p. C-6.)

Moreover, relationships among media, which today are predominantly considered independently, may be better accommodated in a product-oriented systems approach. This approach focuses on the management of the environmental impacts of all players in a pro-

³Dr. Patrick Eagan, personal communication, April 1, 1998. Dr. Eagan has worked with many companies on these issues, including Motorola, AMP, and Boeing.

⁴See PCSD, 1997, and Vermeulen, Kok, and Cramer, 1995, for a more detailed discussion.

duct's value chain as a whole, rather than individual impacts. Chain management is achieved in part through product design.⁵

Therefore, environmentally conscious design, or design-for-environment, may be important to future environmental policy and regulatory regimes. Companies or organizations that successfully implement these practices may be in a more competitive position in the long run.

Private sector experience suggests that design-for-environment can be quite readily pursued in the weapon systems acquisition context. In other words, the private sector is motivated to pursue design-for-environment for many reasons that correspond to DoD's interests in improved environmental management and weapon system acquisition processes. While not transferable one-to-one to DoD's, these motivations are analogous to DoD's desire to:

- Seek cost-effective solutions to weapon system life-cycle environmental issues that ensure military capability and mission readiness in peacetime as well as war.
- Ensure that operators' and maintainers' environmental management needs are addressed and that personnel are adequately protected from environmental, health, and safety risks during operations, maintenance, and disposal.
- Invest in technologies and equipment consistent with future trends in regulatory policies.

DEFINITION OF DESIGN-FOR-ENVIRONMENT

Design-for-environment, like other innovative environmental management practices, is relatively new. Design-for-environment, or environmentally conscious design, encompasses the process by which environmental issues are incorporated into the product realization process. We have defined design-for-environment broadly for the purposes of this study. Design-for-environment is the orga-

⁵The Dutch, considered leaders in sustainability thinking, promote environmentally conscious design as an effective means for chain management (Vermeulen, Kok, and Cramer, 1995).

nizational, legal, and methodological aspects of incorporating environmental issues into design and general management processes. It is the process by which product life-cycle environmental analyses are performed, strategies and priorities are established, and improvement opportunities are identified and implemented. Often, design-for-environment is identified with life-cycle assessments, but the two terms mean different things. Design-for-environment goes beyond life-cycle analysis, which is another analytic technique used to identify, understand, and evaluate environmental effects. Allenby emphasizes the need for a comprehensive, systems-based, and technologically sophisticated approach to design-for-environment (Allenby, 1994, pp. 137–148). Finally, design-for-environment is not a process completely independent of or separate from other management processes. The success of any design-for-environment program depends on its connectivity with these processes and the effectiveness of these processes.

While concepts related to design-for-environment have been around since the 1970s (Office of Technical Assessment, 1992, p. 10), companies only began to develop and employ life-cycle frameworks and design-for-environment formally since around 1989 (Sullivan and Ehrenfeld, 1994, pp. 283–303). Much of the literature, and the Volvo and Hewlett-Packard case studies, shows more significant design-for-environment activity beginning around 1992 (Ufford, 1996; Bast, 1996b; Fräjdin Hellqvist, 1996a; Sullivan, 1996; Azar, 1996).

The standards of the U.N. International Standardization Organization (ISO) do not treat design-for-environment explicitly. The primary standard, ISO 14001, the environmental management systems standard, does not require design-for-environment. Design processes are mentioned, however, as an element of environmental management systems in the associated Annex A guidance document. Nevertheless, continuous improvement, which is required by the standard, may be difficult to achieve without design-for-environment. The other ISO standard related to design-for-environment is the proposed life-cycle assessment standard, ISO 14040. ISO 14040 will contain guidelines for life-cycle inventories, assessments, and improvement analyses that may be employed as part of the design-for-environment process.

DESIGN-FOR-ENVIRONMENT IMPLEMENTATION

Though motivations may be similar among private sector companies, implementation practices vary. There is no “silver bullet” to design-for-environment implementation, primarily because implementation requires integrating design-for-environment processes and goals with core corporate strategies, values, and processes. This deceptively simple statement means that companies or organizations cannot blindly adopt “best-practices techniques.” Relating environmental issues to core values, and integrating them into established management processes, requires insight into the organizational culture and norms. It also requires a solid understanding of such business issues as customer wants and needs, markets, competitive position, and technological aims—for DoD this may be translated into a solid understanding of operator and maintainer wants and needs, constraints and requirements on future operating environments, and alternative technological approaches.

The change process requires continuous leadership as well as patience and time. At the time of the interviews, Volvo and Hewlett-Packard had been developing their programs for approximately six years, and both recognize that the programs are still in their formative stage.

Many companies have introduced design-for-environment through existing TQM processes,⁶ either explicitly (as in the case of Lucent Technologies, Hewlett-Packard, Texas Instruments, and Xerox) or implicitly (as in the case of Volvo) (Dambach and Allenby, 1995, pp. 51–62; Murray, 1995; Ufford and McKelvey, 1996, pp. 88–96; Ufford, 1996).

At its heart, TQM emphasizes three elements (Levine and Luck, 1994; Womack and Jones, 1996):

⁶TQM is a family of management techniques initially developed in the United States in the 1940s, then refined and expanded in Japan during the 1950s, 1960s, and 1970s, and rediscovered in the United States in the 1980s. The many consultants promoting TQM tools and techniques have generated a great deal of confusion about the exact nature of TQM because of their efforts to differentiate products. A well-written introduction to TQM that distinguishes among its variants without getting lost is Dobyns and Crawford-Mason, 1991.

- Identify the organization's customers and what they want, now and in the future.
- Identify the processes in the organization that serve the customers and eliminate as much waste—activity that does not add value to the customers—as possible.
- Monitor performance against the first two goals and continually improve that performance over time.

“Quality” refers to anything the customer values. Many TQM principles are completely consistent with design-for-environment. The TQM principles of process control, continuous improvement, training and empowerment, cross-functional problem-solving, and supplier integration are particularly relevant. Thus, TQM practices generally seek an improved understanding and control of all business processes. Armed with a thorough understanding of such processes, managers and decisionmakers are better equipped to make the cost-performance trade-offs they face continually. An improved understanding of product and process design is one mechanism for seeking cost-effective environmental management.

Elements of Implementation

What has also become clear from the case studies and the literature review is that implementation requires a comprehensive “package” of activities that address different management issues and reinforce one another. It is imperative that each “activity set” be implemented in a way that fits into established practices and other business processes. They must also balance the competing demands or aims of the organization. The five activities or elements common to design-for-environment implementation are:

- Vision and strategy. Senior management clearly articulates the purpose and role for environmental management in such a way that divisions or business units can readily operationalize the guidance. In the leading firms, environmental issues are treated as a strategic business issue. Strategic direction is the key to the proactive treatment of environmental issues.
- Organizational structures. Organizational structures are in place to address environmental issues strategically and proactively,

establish goals and communicate progress toward these goals, and create and share new knowledge and methodologies for design-for-environment. Organizational links are made between levels with clear access to senior management and across units.

- Management metrics and goals. Metrics, aligned with the vision and strategy, are used to focus attention and guide design decisions and investments. Goals are developed by responsible parties and are used to drive action and improvement. Mechanisms are in place to track or assess progress toward these goals and to seek continuous improvement.
- Supplier involvement. Comprehensive environmental management and design approaches incorporate supplier actions and encourage suppliers to share responsibility for environmental performance.
- Training and tool development. Training, analysis methodologies, data and information tools, and other design aids serve two primary purposes. First, they increase the awareness of decisionmakers throughout the organization who affect a product's ultimate environmental profile. Second, they facilitate and guide proper decisionmaking.

These activity sets or elements, common to design-for-environment implementation in private sector companies, are described in more detail in the following chapter and its sections, with specific examples from the case study companies and the literature.

**NO SILVER BULLETS:
ELEMENTS OF A COMPREHENSIVE PROCESS**

Successful design-for-environment programs are comprehensive in that they include the proper mix of strategic guidance and thinking, organizational links that include management support, goal-setting and tracking or assessment, supplier involvement, and analytic tools. There may be excellent activities in any one of these areas, but the successful programs will integrate all of these elements into a complete program. Before each element of successful design-for-environment programs is described in more detail, using examples from the case studies and the literature, some overarching themes are presented.

OVERARCHING THEMES

Design-for-Environment Relies on the Individual Decisionmaker

One of the overarching lessons learned from the literature and case studies of Volvo and Hewlett-Packard is that design-for-environment, by its nature, is a process that involves many individual decisionmakers. The ultimate outcome is a result of the cumulation of many small and large trade-offs made by these individuals. Therefore, successful design-for-environment practices will emphasize improving the individuals' awareness and knowledge of environmental issues as these issues relate to the decisions in their control. It also involves empowering individuals to incorporate envi-

ronmental decisionmaking in their processes. This is accomplished through a variety of means and can include any combination of formal training sessions, networking with the environmental staff, databases, metrics, and decision tools. In addition, individuals are more willing to participate if the rationale for doing so is clearly presented in the context of the organization's core mission. (In these cases, it would be in the context of the profit-making company; in the case of DoD, it would be in the context of meeting mission objectives and ensuring military readiness and capability.) Examples include cost savings, emissions reductions, meeting regulatory requirements, and appealing to growing markets, among others. This involves linking the individual's actions to the attainment of corporate goals and customer expectations. This link is referred to as the "golden thread" at Lucent Technologies (Dambach and Allenby, 1995, p. 53).¹ Information alone is not sufficient—individual decisionmakers, at all levels, must have organizational entities available to assist them in their decisions and to provide guidance and management support.

Design-for-Environment Should Fit Within Existing Processes

Another important lesson is that design-for-environment processes must not add significant time or complexity to existing design processes. Design engineers, product managers, and business managers in general have many demands on their time. Because environmental issues are only one of a multitude of categories that must be considered in design, these processes must be integrated unobtrusively. Activities that minimize the burden on these participants are more likely to succeed. For example, Lucent Technologies established a quick-response group of experts to aid designers on an "as-needed basis," in real time (Dambach and Allenby, 1995, pp. 51–62). Volvo's life-cycle assessment tool performs calculations in minutes and generates one number for ease of use.

¹Lucent Technologies was formerly part of AT&T.

The Design-for-Environment Processes Will Reflect Corporate Culture

A strong rationale for design-for-environment, specific to the organization's activities, should be developed and socialized appropriately throughout. Hewlett-Packard's culture encourages cooperation and decentralized structures. It primarily emphasizes business processes and TQM to implement policies. Volvo, on the other hand, is a little more competitive. Workers there have a strong sense of social responsibility and are generally interested in doing the "right thing." Volvo employs centralized goal-setting, visibility, and training to implement policies.

Introducing Design-for-Environment Is Much Like a Typical Change Process

Design-for-environment implementation is quite similar to any other organizational change process. Organizations seek this change by beginning with small, experimental activities. These are relatively low-risk yet provide useful information on what works, what doesn't, and what new or additional pieces of information might be necessary. The program is then expanded to other parts of the organization by building on the successful lessons from these experimental activities and by relying on the more innovative personnel. Throughout this process, leaders are prepared to change either the approach or specific personnel as new information is gained. Successful design-for-environment practices are then diffused throughout the organization by means of some combination of networking with the innovators, corporate encouragement, and advertisement of success stories.

However, design-for-environment implementation may differ in one significant way from other organizational change processes because environmental issues tend to touch more on an individual's core values. They also involve great uncertainties. So any organizational change must recognize that behavioral change is actually desired and education programs to facilitate this may be warranted (Eagan, 1998; Fräjdin Hellqvist, 1996c; Paulson, 1996).

Recognition that individual decisionmakers were instrumental to design-for-environment, that design-for-environment practices

should be integrated within existing design practices and procedures without adding significant time and complexity, that they must be consistent with corporate culture, and that design-for-environment is much like any other management change process—with the caveat that special attention must be devoted to personal values and environmental issues—were the four overarching themes in the Volvo and Hewlett-Packard case studies. Each of the major elements of design-for-environment programs will now be discussed in greater detail.

VISION AND STRATEGY FOCUS ATTENTION AND AID DECISIONMAKING

The Volvo and Hewlett-Packard case studies illustrate a clear link between treatment of environmental issues and corporate strategy. This is very important to design-for-environment programs because it provides a basis for proactive thinking as well as a focus for analyses and investments. Without such guidance, it could be extremely difficult to ensure that environmental issues are treated early enough in the planning and design processes for cost-effective solutions to be found. Moreover, since rigorous analyses of environmental issues can be quite broad and data-intensive, lack of focus can potentially lead to “paralysis by analysis.” The first component of strategy is the environmental policy, which presents a broad corporate view. This view should reflect an understanding of all the factors that influence an organization, both internally and externally, present and future. The second component of the strategy is the guidance provided to operationalize the environmental policy.

The environmental policy is used to articulate a clear vision for treatment of environmental issues. The policy can communicate the organization’s intent both internally and externally. Often an environmental policy statement will include subsidiary statements or guiding principles that help operationalize the broad policy. The Hewlett-Packard and Volvo policy statements and summaries of the associated guiding principles are included below. Xerox is included as well for illustrative purposes.

- Hewlett-Packard: "To provide products and services that are environmentally sound throughout their life-cycles and to conduct business operations worldwide in an environmentally responsible manner." (Hewlett-Packard, 1993.) Guiding principles are included with the policy. These include ensuring that environmental policies, programs, and performance standards are an integral part of planning, decisionmaking, and total quality processes; facilities are designed and constructed to minimize waste generation and to maximize energy use and ecosystem protection; products, services, and their associated manufacturing and distribution processes are designed to be safe, to minimize use of hazardous materials, to make efficient use of energy and other resources, and to enable recycling and reuse throughout manufacture, distribution, and operation; suppliers support its policy and are encouraged to adopt similar principles; chemical and solid waste generation reduction is sought; and an openness to all stakeholder interests, employee involvement, and active engagement in public policy discussions is promoted.
- Volvo: The environmental policy addresses the broad range of effects that the transportation system has on the environment. This includes land, sea, and air transport's relationship to the environment (e.g., natural resource use, land use, air quality, water quality, all wastes, and noise). The environmental policy explicitly states that making money is Volvo's primary business and only if Volvo makes money can it use that money to help the environment. Environmental programs can contribute to long-term profitability and economic growth of the corporation. Environmental issues should be treated aggressively within the time and scope constraints of long-term profitability. The specific policy elements recognize the need for a comprehensive strategy, to include R&D, product development, and manufacturing; the use of sound materials (especially those that are recyclable); a broad focus on transportation systems; the need to comply with comparable laws worldwide; a similar level of care by suppliers; and factual and open information on the impact of company operations. (AB Volvo, 1994.)
- Xerox: To produce waste-free products manufactured in waste-free factories. At Xerox, waste-free is defined in nine dimensions. These are energy conservation, strategic planning, communi-

cation, use of post-consumer materials, air emissions, solid waste generation, hazardous waste generation, water emissions, and environmental leadership. For example, a factory is defined to be waste-free in terms of energy consumption when energy use at the factory equals 90 percent of the theoretical estimates of what it should be.

As observed at both Volvo and Hewlett-Packard, the environmental policy is the glue that holds the different parts of the corporation together. The companies and units are then free to operationalize the policy in ways consistent with their unique resources, products, and market pressures. In the case of Volvo, the policy was developed by senior functional experts, not the environmental managers. Active engagement by managers in policy development was instrumental in ensuring greater awareness and buy-in by line managers. For Volvo, debate was also an important factor. It built consensus and commitment to the policy. Through the debate, managers internalized their understanding of the policy's meaning and intent (Fräjdin Hellqvist, 1996c).

In both cases, Hewlett-Packard and Volvo have implemented the environmental policy in the context of a business perspective. In other words, it is implemented with full recognition that the company is and should be principally geared toward making money. In the case of Volvo, the policy explicitly recognizes that proper treatment of environmental "performance" can lead to competitive advantage. Thus, environmental issues are treated as other strategic business issues are treated. For DoD, military capability and mission readiness are the primary objectives and proper environmental management can improve weapon system availability at lower cost.

Strategies are then developed based on the vision in the policy statement and the market forces (including regulatory forces) facing the product lines. The strategy provides focus, and in some cases priorities, to design and other environmental decisions. For example, Hewlett-Packard recognizes that mass generation is its top environmental issue. In this case, its strategic attention has been placed on product lines produced in high volumes, as well as those expected to grow in volume. Other areas of interest include energy use and plant emissions. Volvo has a clear hierarchy, which has evolved over 24 years, to its environmental issues of concern. Its

priorities are, in order: energy, emissions, and recycling. Goal-setting is complicated at Volvo because these priorities are not mutually exclusive or independent of each other. As a result, progress toward these goals can be difficult, requiring lots of analysis and judgment, or it can be straightforward and simply a matter of awareness and concern. Communication of strategy and priorities helps designers and line managers have a better understanding of which attributes are important and why.

Strategic focus is also used to provide investment flexibility, which is another element of successful environmental management and design-for-environment. Environmental managers from both 3M and Xerox stated that occasionally environmental investments were not made exclusively based on strict financial criteria (Zosel, 1995; Azar, 1996). Rather, senior management recognizes the importance of these investments to corporate strategic direction and is willing, at least in the short run, to invest before financial criteria are met. While the speakers did not explicitly state that proactive management on environmental issues can lead to competitive advantage, their statements can be interpreted this way. Claude Fussler of Dow Europe points out in his recent book, *Driving Eco-Innovation*, that the success of persistent, competitive companies, especially those in high-technology markets, such as GE Medical Systems, Motorola, and Corning, can be attributed to their long-term, strategic view (Fussler with James, 1996, Part II). In particular, they achieve this "by combining a long-term perspective with a culture of continuous change and improvement." Investments are not guided solely by financial considerations but with long-term strategy in mind.

Financial considerations are constraints on general management decisionmaking rather than its determinants. In every case, once a course of action is deemed strategically necessary or desirable, financial considerations determine the pace and approach, and they are the ultimate measure of performance. But the decisions about whether to set out on or to continue the course of action are shaped by strategic considerations. For any major potential investment, the driving question is: "Given that we are committed to this area of business, what steps must we take to stay ahead?" rather than, "Given that we must achieve a certain rate of return from our investments, is this a wise investment?" (Fussler with James, pp. 19–20.)

There are several lessons regarding environmental policy and strategy. First, the environmental policy clearly articulates corporate environmental objectives for internal and external communication. It is the common thread linking all parts of the organization. Second, the environmental policy objectives are stated in business terms and see the environment as one factor contributing to strategic advantage. Finally, the strategy, which incorporates the environmental policy, its guiding principles, and an understanding of environmental issues as they relate to the organization's mission and market forces, is used to focus management attention, analysis, and investments over the long term.

For DoD the environmental policy is the common thread between the armed services and weapon system program offices that makes the connection between environmental planning and management and mission capability and readiness. Guiding principles for its implementation would help the services and program offices. The policy can then be used to determine a strategy—in the case of DoD this probably means multiple strategies, one for each class of weapon system—to focus management on the important environmental aspects in light of the many demands on program managers' time.

ORGANIZATIONAL ASPECTS ARE THE MOST CRITICAL TO DESIGN-FOR-ENVIRONMENT IMPLEMENTATION

You must build the bridge before you can cross it. (Fräjdin Hellqvist, 1996a.)

[F]ully implementing design-for-environment practices will require that most firms develop new competencies, organizations, and information systems as well as changes in organizational cultures. (Allenby et al., 1995, pp. 51–62.)

Experience in industry to date indicates that organizational and psychological barriers to the introduction of design-for-environment are frequently far more significant than lack of appropriate technology. (Dambach and Allenby, 1995, p. 58.)

As the statements above suggest, the organizational elements of a design-for-environment program are perhaps the most challenging. They also are the most important to address early. In many instances, it is easier to focus on logical tools, such as life-cycle assessments, than on the complexities of the organizational and psychological barriers to change (Dambach and Allenby, 1995, p. 59). However, without the organizational mechanisms to both drive and implement the findings of these analyses, there will be no progress.²

Many similarities in the organizational structure used to implement design-for-environment can be found at Volvo and Hewlett-Packard. The most striking is the use of parallel organizational structures and networking to make decisions and to transmit information both up and down the management chain, as well as across different organizations within the company. In both companies, environmental councils made up of key functional managers at the corporate level generate environmental policies.³ These councils are either composed of the senior managers who determine the strategic thrust of the company or they have direct links to these senior managers. Working groups, supported by the corporate council, operationalize the broad policy. At each business unit to the specific product line and design team, networks of working groups and individuals are responsible for integrating environmental issues into the decision-making processes associated with design or new product development.

For example, at Hewlett-Packard two bodies contribute to its product stewardship program at the corporate level. The Hewlett-Packard

²One company contacted had spent more than five years developing a sophisticated life-cycle assessment model in its development center. However, life-cycle analyses had not been performed in product designs, in part, because the model had no organizational home in the product divisions.

³AT&T, and now its former subsidiary Lucent Technologies, also has a Design-for-Environment Coordinating Team with broad, cross-functional representation from the business units and support organizations (Dambach and Allenby, 1995, p. 59).

Environmental Management Steering Committee develops overarching environmental, health, and safety policy and procedures for environmental management in general. It is a high-level committee that sponsors the product stewardship activity. The Product Stewardship Council aids the individual product stewards with information, policies, and processes specific to product stewardship or design-for-environment, ensuring that these are consistent and integrated with other business practices. Environmental stewards, responsible for incorporating environmental issues into design decisions and processes, are identified within each product line. They are the critical link to integrate environmental issues with other business issues and their market knowledge and business expertise are vital. These stewards are guided and helped by both the business and the corporate levels. The decentralized structure is quite consistent with Hewlett-Packard organization in general. Frequent communication among the product stewards across the company, as well as among the stewards and designers, is very important.⁴

At Volvo, the corporate Environmental Board and Council address issues of corporatewide importance to ensure consistency and appropriate action. Its environmental organizational structure includes a high degree of senior, line management participation. Each company in the corporation designates an environmental manager to implement corporate environmental policy. Management processes are in place to eliminate discrepancies across companies, if they develop, and to verify that corporate environmental policy is followed. Environmental policy boards with decisionmaking authority exist at all levels of the corporation—corporate, company, and unit. This parallel organizational structure aids the flow of information to and from senior managers as well as across companies or units.

At the company level, experts from Volvo Car's Environmental Competence Center work with design teams and engineers to attain product-oriented goals. Because of the general Volvo corporate cul-

⁴Because the product steward job is still evolving, specific skills have not been explicitly enumerated. However, a strong ability to communicate and understand both the division or product-line strategy and the design process is very important. Individuals with R&D, marketing, or manufacturing experience most often have the requisite knowledge of market, product, and business issues.

ture, most management processes rely on competition, cooperation, and competence development. Environmental Competence Center personnel actively inform and remind others of motivations to consider environmental issues and attributes.

Environmental Competence Center personnel interact with design organizations at several levels. At the management level, the center director reviews strategic issues with each of the design departments for a particular product and builds political support and visibility for environmental goals. At the working level, competence center personnel engage design teams directly to develop and monitor environmental performance attributes. At the skill level, the center co-develops tools and educates engineers on the environmental effects of their designs to help develop new competencies. Individual competence is especially important because new product design is characterized by decentralized decisionmaking and many design trade-offs.

Finally, at each of the companies there is an individual who is responsible for integrating environmental issues into design processes. Other companies, such as Lucent Technologies and Texas Instruments, also have identified points of contact, champions, or liaisons between the engineering design function and the environmental specialists. Generally, employees with an understanding of market forces and the challenges of product design are selected for this role.

In many cases, traditional environmental staff members are used as consultants. Volvo's Environmental Competence Center provides a central home for environmental experts. Lucent Technologies has a quick-response team of experts to help designers with difficult questions in real time. They inform and engage decisionmakers. At both Hewlett-Packard and Volvo, it is recognized that individuals in the design, marketing, and research and development organizations, to name a few, are the ultimate decisionmakers. A survey of 26 industrial firms had similar findings—that the organizations most actively involved in life-cycle work (broadly defined to include design-for-environment and other life-cycle activities) were marketing, product design and development, research, health, safety, environment, and manufacturing. Moderately involved are strategy, process design, product teams, and purchasing. Rarely

involved at the firms surveyed were the finance, accounting, and legal departments (Sullivan and Ehrenfeld, 1994, p. 293).

The organizational arrangements described above serve several purposes. First, because of the corporate-level executive board structure, a clear organizational tie links design-for-environment activities with strategic business activities so environmental issues will be related to the company's primary objectives. This link also ensures high-level management support and attention when necessary. Second, these arrangements empower the functional experts responsible for making the decisions that will ultimately affect environmental concerns. Third, the parallel structure facilitates the flow of information to guide decisions, and the integration of environmental staff with functional experts helps to build awareness and new competencies where necessary. Fourth, the organizational links provide venues to address issues of mutual concern and to develop common analysis and assessment tools across units. Finally, champions are identified to facilitate the incorporation of environmental issues into design processes and decisions and to help move the program forward.

If DoD were to follow a similar model, information should flow between the functional and product-oriented organizations. For DoD the equivalence is as follows: corporate-level boards are equivalent to OUSD Acquisition and Technology, Installations, Logistics, Defense Advanced Research Projects Agency (DARPA), Deputy Director of Research and Engineering (DDR&E), with input from Environmental Security; the services are analogous to the business units with their own sets of functional organizations; the program offices and defense contractors are analogous to the product-line design teams; and the JG-APP represents operators and maintainers, which are analogous to the private sector's customers. Processes and mechanisms to ensure the flow of information within and between these organizations should be established. Because of the complexity of DoD's structure, having identifiable product environmental "champions" becomes even more crucial than in private industry.

MANAGEMENT METRICS AND GOALS

Environmental strategies and organizational structures are two important elements of a design-for-environment program. Another important element is the use of management metrics and goal-setting. In both case study companies, management metrics, aligned with the vision and strategy, are used to focus the attention of designers and other decisionmakers. Furthermore, they are used to guide design decisions and investments. Specific goals for the metrics are developed by the responsible business units or product development teams. And goal-setting is used to drive action and improvement. Progress toward achieving the goals is tracked, but different mechanisms may be in place to accomplish this.

Metrics Reflect Corporate Strategy, Regulatory Issues, and Market Values

Sample metrics from the case studies are shown in Table 4.1. These metrics reflect the corporate strategy that emphasizes certain environmental characteristics. Volvo Car Company is concerned about energy use, emissions during operations, recyclability, sustainability, and plant emissions. Hewlett-Packard is focused on these as well as reducing the amount of solid mass generated—hence its interest in disassembly and recyclability. Because in most cases there are interdependencies between the metrics, a framework to integrate these metrics, or a prioritization scheme, makes trade-offs easier.⁵ It also makes communicating decisions easier.

In the case of Hewlett-Packard, the metrics listed are suggested by corporate. Each product line is free to select from this guide according to the issues and market conditions of particular concern. Hewlett-Packard has also established the following ground rules for its metrics:

⁵Volvo uses its long-established priorities and its life-cycle assessment tool called the Environmental Priorities Strategies (EPS) to frame its decisionmaking. This benefit of structured analysis was also reflected in a survey of 34 companies in the chemical, electronics, and consumer products industries. Companies reported that the overwhelming benefit of life-cycle assessments was their aid in establishing priorities and enabling decisionmaking (Gloria et al., 1995, p. 45).

Table 4.1
Sample Management Metrics

Volvo	Hewlett-Packard
Energy Use Fuel consumption (CO ₂)	Materials Conservation and Waste Reduction Mass or weight Percentage reused Percentage recycled
Emissions (VOCs, etc.) CO, HC, NO _x , PM	Energy Efficiency Normal operating mode watts Sleep-mode or power-down watts Off-mode watts
Recycling/Waste Management Percentage recycled	
Sustainability Use life-cycle assessment	Manufacturing Emissions SARA 313 emissions Hazardous waste generated Hazardous waste reused/recycled Site solid waste generated Site solid waste reused/recycled
	Design-for-Environment Variety or number of materials Plastics marked Recycled material content Materials requiring special handling

SOURCES: Fräjdin Hellqvist, 1996c; Korpalski, 1994, p. 209, and 1996, p. 40.

- Metrics should be simple and easy to apply.
- Metrics should focus on strategic issues (those that regulations, standards, or the customer will require) and should incorporate knowledge gained from the field (particularly recovery centers).
- Product designers should have the ability to influence the values of the metrics.
- Metrics represent a starting point for environmental improvement strategies and do not reflect a full-blown life-cycle analysis.

The literature suggests that metrics be broad enough to reflect overall environmental performance trends and yet detailed enough to meaningfully convey potential opportunities for improvement. If metrics relate to primary or core organizational activities, then more

individuals can share responsibility and act to seek improvement in these measures. Once metrics are defined, reliable mechanisms must be created to collect, analyze, and report them. A management strategy involving everyone must also be developed. Once environmental performance is presented in terms that the core business can understand and embrace, then the responsibility for performance and improvement can be shared by the entire plant and management staff (Haines, 1993, p. 368).

Because DoD is both a monopsony buyer and a design partner, it has no exact analogies in the private sector. This unique position gives it more leverage with its suppliers, the defense contractors, than the private sector generally has with its suppliers. Because of its shared role in program management and design of complex systems, coordination with suppliers becomes even more imperative. For these reasons, developing good management metrics is probably more important to DoD than to private sector design-for-environment programs.

Goals Are Determined by the Responsible Parties

The specific values or goals identified against these metrics are established by the business units responsible for achieving them. Goal-setting often involves consensus-building along the management chain and sometimes competition between product lines to establish values.

At Hewlett-Packard, armed with strategic market and regulatory information from a corporate design-for-environment database, support from the organizational links across the division as well as the company, and their own understanding of the specific product market and business issues, the product-line stewards integrate environmental issues into the design process with design guidelines and product metrics. Product teams and product-line stewards have considerable latitude in determining not only which products should be assessed in what years, but also which metrics to apply and what values or goals to establish. An important part of the product-line steward's role is to integrate all this information, to select the metrics that are relevant to the product for which he or she is responsible, and to co-develop goals in cooperation with the product-line manager and team. Thus, the product-line stewards work with the design

team to apply the design criteria developed at corporate to the particular product.

At Volvo, the company establishes its goals, which are reviewed by the corporate Environmental Board. Two features of the goal-setting process appear to be the most critical. First, there must be a framework to guide goal-setting and decisionmaking. Once a goal is selected, it is transformed into a clear target and progress is tracked against that target until it is achieved. Second, the goals are built through intensive networking between the environmental group experts and the other functional units.

In any decisionmaking process, many trade-offs take place, and a structure or framework helps make these trade-offs easier to assess.⁶ Having a framework aligns investments with company strategy and provides a means to prioritize those contributing the most to strategically desired environmental improvements. Moreover, it focuses management attention on the important issues and facilitates action in a technical environment, which is highly quantitative. Finally, the structured goals and targets help to relate specific activities to company goals.⁷ The Volvo Car Corporation (VCC) framework for goal-setting uses a combination of established priorities and life-cycle thinking to integrate the set of measures and goals. VCC's priority for investments is clear: first business, then safety, and then environment. VCC then focuses on stages of development with the greatest leverage over the life cycle.

⁶Walley and Whitehead (1994) point out that one of the problems with Porter's win-win paradigm, under which stricter environmental standards can trigger innovations that lower a product's cost or improve its value (Porter and van der Linde, 1995, pp. 120–134), is that searching for these opportunities can divert too much management attention from other core business processes. An example of a win-win situation found in a structured way was at Volvo's Torslanda plant. The plant performed a waste management study over a two-week period and found a way to save \$3 to \$4 per part through packaging reduction without any investment. This structure is provided by the combination of organizational entities, the life-cycle framework, goals, and priorities.

⁷The use of long-term strategic planning to guide investments that meet financial criteria is recommended by Claude Fussler, Environmental Health and Safety, New Businesses and Public Affairs, Dow Europe. The long-term view allows innovative companies to persist, to better anticipate major technological changes, and to exploit this change for their competitive advantage. Given the three drivers of environmental issues—population and demographics, environmental stress, and value creation—he anticipates significant innovations in the future (Fussler, 1996, pp. 20–21).

Second, the goals are built through intensive networking between the environmental group experts and the other functional units. The environmental experts motivate line organizations to consider environmental effects, provide expertise on environmental issues, help to relate actions of the functional units to specific environmental measures and goals, and create visibility for these goals and build political support for their realization throughout the company and among all managers. This process relies heavily on raising individual awareness and competence or analytic skills with respect to environmental performance. The line experts are responsible for actually incorporating environmental concerns into their analyses and decisions.

Networking is performed in all settings—design, advanced engineering, production, etc.—and is reinforced by the environmental boards and working group organizations.

The Environmental Competence Center works with the advanced engineering department and design teams and engineers to attain these goals. At the management level, it reviews strategic issues with each of the design departments for a particular product. At the working level, the competence center staff engage design teams directly to develop and monitor environmental performance attributes. At the skill level, the center co-develops tools and educates engineers on the environmental effects of their designs. The company's environmental training provides a common basis of understanding for dialogue within and between all levels.

Goals are based on some combination of regulatory drivers, corporate strategy, competitor actions, and market interests, while the framework for decisionmaking guides trade-offs and decisions. Ultimately the engineering department or design teams determine the specific value that will be achieved. These functional units have the expertise required to provide feedback on the feasibility of the goals and to offer suggestions for ways to meet the goals. The Environmental Competence Center is responsible for monitoring the political, economic, and environmental aspects of issues as well as technical capabilities. These trends are then combined with business development needs to contribute to the R&D agenda so that technical capability is ready for product lines as needed.

Texas Instruments has a process for goal-setting that it calls "catchball." During its goal-setting process, the business units identify year-by-year improvement goals and share them with other units as well as with upper unit management. This helps build consensus around a goal and creates buy-in to eliminate the barriers that may hinder achievement of the goal (Ufford, 1996; Ufford and McKelvey, 1996, p. 91).

Because of its culture, any goal-setting process for DoD would most likely be more effective if it employs the approaches taken by Volvo Car Corporation and Texas Instruments. This would primarily involve DUSD Environmental Security and the service environmental experts working with the champions or points of contact in the acquisition program offices and research agencies.

Progress Toward Goals Is Tracked

Most of the companies in the literature and case studies monitored progress toward the goals, through either formal reviews or audits. Hewlett-Packard and Volvo differ in their approach to tracking progress. Hewlett-Packard has a more decentralized process than Volvo.

Hewlett-Packard uses self-assessments to track the progress of the product stewardship program (this is consistent with its decentralized and cooperative corporate culture). Self-assessments were developed to help product-line and business managers evaluate their own programs. They are a way to engage business managers through their own self-evaluations of their product stewardship program and are not intended to have an audit function. Evaluation is performed through a structured process that involves division or product-line stewards as well as relevant functional managers. The core of the assessment is a series of TQM-system-type questions that the product steward asks of these senior managers. These provocative questions are action-oriented, not answer-oriented. For example, they include:

- Who is the management sponsor of the product stewardship program?

- Does the sponsor have a customer tracking system in place to understand customer needs and expectations?
- Are environmental issues incorporated into the supplier selection process?
- Are product guidelines available to all product lines?

If managers cannot answer this series of questions, they probably do not have a comprehensive management process in place. The questions cover the broad areas of market knowledge (including customer expectations, the implications of voluntary standards to each product line, and competitor actions) as well as management processes (including business product steward links to corporate and other businesses, an internal management sponsor, business- or product-specific design guidelines, supplier evaluations, and mechanisms to ensure internal awareness and communication of product stewardship principles). As a result of this self-assessment, action items may be generated and progress can then be tracked by the business itself from year to year. Early feedback also shows that these self-assessments helped elevate awareness about the purpose and benefits of the product stewardship program. Hewlett-Packard product stewards believe that the program will not succeed by mandate—it will only succeed and survive if product managers and others see the benefits.

Volvo, on the other hand, relies more on a top-down review and competition between companies and units in the goal-setting process to drive improvement. Volvo's corporate Environmental Board challenges the companies every year to set goals. It is up to the companies to set their specific goals, but the corporate Environmental Board reviews them. The Environmental Board will revise them if the goals are either too challenging or not challenging enough. Individual companies' goals are compared to provide cross-fertilization. Comparison and discussion also help raise issues that may not have been considered previously by the companies when they set their goals. They also generate some competition. There is spirited competition between the companies (VCC and Volvo Truck are particularly competitive), but this is not driven by expectations of financial rewards.

Periodically, a corporate environmental auditor also performs environmental audits with staff from the various companies.⁸ These audits have three purposes:

- Evaluate compliance with existing legislation.
- Assess compliance with likely future legislation.
- Assess implementation of corporate environmental policy. (AB Volvo, 1995.)

Internal audits are a mechanism to evaluate progress in a rigorous and consistent way—they force managers to take a hard look at what they are doing in a structured manner. Audits are also used to transfer lessons learned to other parts of the company or organization. Performance on audits can also be used to generate a healthy competition between business units.

Other companies use various mechanisms to track progress toward product-oriented goals. For example, Xerox uses its design review process to ensure that specific product design criteria are met (Azar, 1996). It uses self-assessments at manufacturing facilities to provide overall waste-free factory scores, which are then compared to the corporate goal of waste-free factories by 2000.

Several lessons emerge regarding goal-setting. First, a baseline system, or definition of green product, based on the strategic interests of the organization, is necessary. Second, targets or values are established based on specific product characteristics, market pressures, customer interests, and regulatory requirements. Third, the target values are determined by the business unit responsible for attaining them with the help of the product stewards. Fourth, the role of corporate management varies in the goal-setting process, but there is always some involvement. Sometimes competition between business units is used to establish goals and progress tracked. Finally, continuous improvement is sought. Goals are tracked (Volvo) or progress is assessed (Hewlett-Packard) in a structured and consistent manner.

⁸Audits are comprehensive. In addition to organizations within AB Volvo, they review the systems of major suppliers, waste-processing firms, and companies in the process of being acquired.

DoD's culture probably requires some top-down guidance and review in any goal-setting process. This may mean that OUSD Acquisition and Technology would take the lead in tracking goals developed for a set of program-related metrics that bear on the strategic or key environmental issues determined for each weapon system type. These metrics could include the number of hazardous materials employed in the weapon system, solid waste generation during operations, and the time between maintenance actions. Each program office and defense contractor team would set its own goals and determine the investments required to attain each goal. This analysis would be vetted through the DAB. Weapon system goals would be shared with other weapon system programs as well as with potential operators and maintainers, perhaps through the Defense Environmental Network Information Exchange (DENIX). Audit teams organized by USD Acquisition and Technology and DUSD Environmental Security could review programs annually.

SUPPLIERS ARE PART OF THE VALUE CHAIN

All of the companies that practice design-for-environment as described in the literature and case studies include suppliers in their processes to some degree.

Volvo and Hewlett-Packard explicitly recognize that suppliers contribute to product and process goals. True systems-oriented design approaches will consider supplier contributions to product and process goals. Many companies, including Lucent Technologies, Volvo, and Xerox, incorporate suppliers directly in their life-cycle analyses used to develop a strategic focus for management attention, further analyses, and investments. Xerox personnel recognize that, as new products are designed for multiple life cycles through remanufacture, it is important to bring in the expertise (and the capacity) of equipment suppliers. Therefore, Xerox engineers work closely with the suppliers in the design process to improve product designs for remanufacture, to encourage the use of recycled material, to improve labeling, and to develop better materials recognition systems for sorting (Azar, 1998).

However, suppliers are included in design-for-environment processes to varying degrees. Companies' most common and direct mechanism to influence suppliers is the procurement process. The

two most common approaches are to include environmental criteria in the overall supplier selection criteria (Hewlett-Packard, Texas Instruments, Volvo, Xerox) or to include environmental specifications.

At HP, the Product Stewardship Council developed a set of source selection criteria for the suppliers. This set is included with other supplier criteria in the categories of technology, quality, responsiveness, delivery, cost, and environment (TQRDC-E). There are two levels of supplier criteria: corporate criteria and product-specific criteria. In order for a criterion to be included at the corporate level, it must satisfy two conditions. First, it has to be of concern globally. Second, the criterion has to be vetted with suppliers before it is included in the source selection process. The specific environmental corporate criteria, or "E criteria," are as follows:

- Existence of an environmental policy supported by top management. HP suggests that the policy cover manufacturing processes, materials and labels, source reduction, power consumption, reuse and recycle, packaging, and disposal.
- An implementation plan with metrics tied to the supplier's environmental policy.
- No use of ozone-depleting substances.

Supplier performance against these criteria is then evaluated and compared to that of other suppliers of the same commodity. These results are included in the overall supplier performance rating that covers technology, quality, delivery, cost, etc.—the TQRDC-E.

This standard HP supplier evaluation process continues through contract execution. During source selection, suppliers are rated against these criteria. For the environment category, this rating process is somewhat subjective. Generally, HP divisions and purchasing agents want to see an environmental policy that fits the supplier's corporate culture, complies with its country's laws, provides cost savings, and yields competitive advantage. If these conditions are met, HP hopes these obvious advantages would provide enough incentive for suppliers to comply—because HP feels that, for the most part, it lacks strong control over its suppliers. HP is reluctant to audit its suppliers because, in its view, that would be micro-

managing, and HP does not have that much power over an individual supplier.

Xerox goes one step further and requires suppliers to certify compliance with the environmental objectives and requirements put forth prior to authorization as an official Xerox vendor (Xerox, 1997b). A survey performed for a study of supplier relationships in the computer industry indicates that in 1991 environmental issues were more important to purchasing managers when selecting suppliers than they were in 1986. The increase in the importance of the environmental criterion was larger than the changes in the other supplier selection criteria of quality, price, long-term relationships, flexibility, delivery lead time, and stability. Environmental issues, however, were still the least important criteria (Berube, 1992, pp. 44-45).

Often suppliers will be required to eliminate certain materials or chemicals from their products. For example, Hewlett-Packard requires that there be no ozone-depleting substances (ODS) in supplier products; Volvo requires that all chemicals on its blacklist be excluded from supplier products; and Xerox restricts suppliers from using environmentally sensitive materials in products made for Xerox. As part of its contractual relationship with its suppliers, Xerox requires compliance with applicable EH&S regulations, products that do not contain or are not manufactured with ozone-depleting substances, packaging free of toxic heavy metals, plastics marking, and cooperation to achieve the environmental leadership-driven goals for product design (such as asset recycle management). In this way, Xerox communicates market environmental requirements (for example, prohibition of such materials as polybrominates) to its suppliers (Xerox, 1997b).

Generally, companies look for suppliers to have environmental policies and management practices to implement and enforce the policy (e.g., Hewlett-Packard and Texas Instruments). Volvo further specifies that the environmental policy is "in the spirit" of its environmental policy. Xerox requires that vendors implement an environmental management system (EMS) that conforms to ISO 14001 or the European Eco-Management and Auditing Scheme (EMAS) within three to four years to be eligible for "preferred" vendor status (Xerox, 1997b, p. 20).

Suppliers can be integrated into environmental management in other ways. For example, Texas Instruments involves suppliers in its "catchball," or goal-setting, process. Volvo Car Corporation includes major suppliers and dealers (sales and service personnel) in its environmental awareness and training program, the Dialogue program. Lucent Technologies plans to integrate the environmental performance information of suppliers into existing design databases, and this information will also be available to the final customer (Ufford, 1996; Allenby et al., 1995).

Finally, all companies note that it is much more effective to work cooperatively with suppliers to solve problems than it is to use product specifications to dictate requirements. Joint problem-solving and goal-setting are much more effective approaches to improving environmental outcomes than mandates are. The key to success is to work as a team toward environmental ends.

DoD is already working closely with its suppliers, and environmental performance is included as a criterion in the source selection process. Consequently, private sector experience has little to add in this area. Two thoughts come to mind, however. Private sector companies have been clear and direct in their environmental requirements for suppliers, even when buyer position is not as dominant as the DoD position. If these issues are important to DoD, and this importance is communicated, its suppliers will respond. Second, a robust set of shared program environmental metrics may make dialogue more productive, communicate priorities, and catalyze joint problem-solving. Metrics are more critical in light of the fact that DoD's suppliers perform much of the design.

TRAINING AND ANALYTIC TOOLS

Training, analytic tools and methods, and other design aids are important elements of design-for-environment because they address the behaviors and the needs of the individual decisionmaker. It is the *individual* who is the linchpin to any program or process. In a comprehensive design-for-environment process, appropriate decisions and actions are guided and reinforced by management, the organizational networks, goal-setting processes, and communication with the environmental experts. However, the individual decisionmaker ultimately determines the success of the design-for-

environment process. Training and analytic tools serve two fundamental functions. They (1) increase the individual's awareness of environmental issues and develop new skills or competencies to address them and (2) facilitate and guide decisionmaking by providing timely information and analytic structure.

Training

Training in the context of design-for-environment seeks to improve the individual's appreciation and awareness of environmental issues and to develop new competencies for dealing with these issues in the normal course of work. According to training professionals, "Education can be a powerful potential change agent for companies" and can provide a common vocabulary for all participants (Eagan, Koning, and Hoffman, 1994). However, "The curriculum must stimulate a combination of attitudes and behavioral changes as well as the acquisition of new skills." To most effectively motivate behavioral change, the learning process must address what is called the "affective domain," or an individual's value system and attitudes toward the subject matter (Eagan, 1996, pp. 3-5). This kind of change is challenging because corporate values, which define how employees are expected to act, are operationalized through a myriad of ways. Often, employees confuse a change in the operationalization of a value with a change in the core value itself, making even small changes difficult to implement (Leonard-Barton, 1996).

Indeed, Volvo has found that actually integrating environmental issues with business decisionmaking is difficult because environmental issues touch on the individuals' core values and ethics. And these can vary among individual decisionmakers. Volvo environmental personnel have found that if environmental effects can be put into monetary terms, then personnel will respond more readily. For example, Volvo can easily make the business case for recycling—if Volvo products do not meet the requirements of the Swedish recycling law, then Volvo will have to pay a fine, which may mean raising the price of the automobile or earning less profit.⁹ Its Dialogue environmental awareness and training program is provided

⁹The Swedish recycling law requires 85 percent of the automobile to be recyclable by 2002.

to all Volvo Car Corporation employees worldwide, dealers (both sales and service personnel), and suppliers. The Dialogue program is geared toward modifying employee attitudes and values toward the environment by giving employees the information to do so.¹⁰ Employees' attitudes are surveyed periodically to determine the effect of training and awareness programs, and the results have shown a change in attitude. The common training throughout the organization also facilitates communication on environmental issues by providing a common level of understanding. For comparison, Texas Instruments has a program more tailored to design. Its "Winning Designs" briefing is given to all company designers worldwide. This briefing seeks to increase the designers' awareness of environmental issues, and it covers environmental, safety, and health concerns that may be related to design decisions (Ufford and McKelvey, 1996, p. 92).

Overall, little information is available on specific training demands for implementing design-for-environment. Formal design-for-environment training appears to be focused on specific models or methods that are company-specific. The observations of a design-for-environment educator regarding design-for-environment course curriculum are:

- Design-for-environment curriculum development is very firm-specific.
- Many courses have a separate environmental awareness component.
- Course components on business and accounting were important.
- Some used industrial ecology concepts to frame the discussion.
- Every company focused on a specific design-for-environment tool or model relevant to its own design process (Eagan, 1996, p. 3).

¹⁰Safety is the highest corporate core value and has been part of training since the company's inception in 1927. To make environmental concerns as well known will be more of a challenge. Because safety is a more immediate life-and-death issue, its importance is easier to explain than that of the environment, where the issues can be longer-term and indirect.

Analytic Tools

Many types of analytic tools or design methodologies are important to any design-for-environment process. The primary purposes of these tools are to provide information and guidelines to aid structured decisionmaking and encode corporate or company values for the individual. Any particular analytic tool may be more applicable to a given design phase, and more than likely multiple tools or methodologies will be important to develop for a complete program. According to Texas Instruments' David Ufford:

The development and maintenance of effective design-for-environment guidelines requires an understanding of the cause-and-effect relationship between product characteristics and their associated environmental effects. This relationship is often difficult to establish and may require the investment of significant time and resources. (Ufford, undated.)

While an in-depth examination of the analytic tools used in design is too broad for the purposes at hand, some exemplary information on the kinds of tools used is provided.¹¹

A survey of analytical tool use in companies in major industrial sectors was performed by researchers at the Massachusetts Institute of Technology (MIT). They categorized the resources and tools that designers are most likely to use, with the number in parentheses indicating the amount of use—1.0 represents “always used,” and 0 stands for “never used.” Their findings are as follows: issue-specific consultation from environmental staff (.6), explicit environmental design constraints or goals (.5), guidelines for environmental design (.4), checklists of environmental concerns (.4), databases of environmental impact data (.2), and environmental design software (.1) (Lenox, Jordan, and Ehrenfeld, 1996, p. 28).

¹¹There is a large body of literature that addresses methodological and data issues in this area. If the reader is interested in learning more specifics about available tools see: EPA (1993a), EPA (1993b), EPA (1995), Society of Environmental Toxicology and Chemistry (1991), Institute of Electrical and Electronics Engineers (1995), as well as various IEEE Conference Proceedings and Air and Waste Management Association Conference Proceedings.

As mentioned, depending on the design phase, different tools that use different data may be employed. The design team can use these analytic tools in several ways. First, they may be used to *screen* or narrow design choices by providing either threshold limits for particular properties, such as NO_x emissions during operations; material priorities based on toxicity or recyclability; or environmental performance criteria for suppliers. Second, they may be used to *assess* the environmental performance of designs by identifying emissions and wastes generated during manufacture and operations, for example, or by profiling cost and emissions data during the life cycle. Third, they may be used to *trade off* several dimensions of cost and performance attributes among various design alternatives. This may include identifying the interactions between such design features as eco-efficiency, cost, performance, producibility, or reliability and maintainability. Or it may mean assigning relative importance to the different impacts. Fourth, they may be used as *decision support* to help design teams select from alternatives when uncertainties or complexities are great.¹²

Analytic tools used for these purposes can be grouped into three broad categories of importance to any design-for-environment process: engineering and design tools, accounting methods and tools (particularly activity-based costing and life-cycle models), and program or process control techniques. There is less information in the general design-for-environment literature about specific accounting and process control techniques than about engineering and design tools, so the following discussion reflects this emphasis.

Engineering and Design Tools

Common engineering and design tools discussed in the literature and case studies include design checklists, design strategies, design guidelines, preferred materials lists, computer-aided design (CAD) tools, and life-cycle assessment (LCA) models. For example, Lucent Technologies uses a simplified life-cycle assessment method, which is a series of matrices that identify the relative magnitude of environmental effects for each phase in the product life cycle. The

¹²Fiksel (1996), pp. 52–53, suggests these four categories for use of analysis methods.

information is incorporated and presented qualitatively and does not use complex and data-intensive algorithms. Lucent Technologies emphasizes getting started and learning as it goes (Dambach and Allenby, 1995, p. 60). Lucent Technologies also uses a "green" index design tool with its CAD system to help design engineers select environmentally responsible attributes and score the design based on eleven attributes. The index is also a useful education vehicle. This design tool is on-line and provides quick response (Allenby et al., 1995, p. 5). Texas Instruments employs design-for-environment guidelines, a tutorial on design-for-environment drivers and principles, lists of hazardous materials, and trade studies. These tools and others are included in an on-line information system (Ufford and McKelvey, 1996, p. 92).

At Hewlett-Packard, corporate design guidelines were developed by the Product Stewardship Council, select business-level product stewards, and personnel from manufacturing, procurement, marketing, alternative sourcing and recycling, and R&D. To develop these guidelines, the staff did not perform a full-blown life-cycle analysis of all environmental effects. Rather, they worked through the product value chain from R&D through disposal and performed a gross assessment of the environmental effects. Using the results of this gross-level analysis, they developed a set of generic design-for-environment guidelines that can be applied as appropriate to all Hewlett-Packard products. These guidelines are broad and generic enough, irrespective of the specific product, to help position the product better on environmental issues. Guidelines cover the areas of product use, packaging, consumables and supplies, manufacturing processes, and end-of-life strategy. Among other aims, the guidelines are intended to reduce mass, eliminate hazardous materials, and reduce the number of components. Some of the guidelines were easier to develop because of the company's experience recycling and reusing parts in its Roseville, California, and Grenoble, France, recovery facilities.¹³ Once the guidelines were created, they

¹³HP began a recycling facility in Roseville, California, in the late 1980s as an alternative method to generate parts for servicing (rather than tying up manufacturing facilities to generate these parts). This center was not originally developed for environmental reasons, although there is an obvious benefit. The center is profitable in part because it recycles or reuses *select* parts. In some cases it might make sense to reuse parts, extend the design life, reuse components, or scrap materials. This center's

were spread to the product stewards worldwide through the Fountainhead database, which is an information resource shared companywide.

The Hewlett-Packard Fountainhead database is the primary formal vehicle for information exchange among the corporate, the division, and product-line stewards. Included in the database is information on worldwide environmental trends, both market and regulatory, as well as the corporate environmental policy and principles, product steward points of contact, design guidelines, suggested metrics, benchmarking data, and meeting notes (a schematic of the database is shown in Appendix B). Xerox has a similar system, called the Regulatory Tracking Network. This information system contains data on worldwide regulations, standards, and voluntary initiatives for the markets relevant to Xerox businesses. This information is disseminated through a variety of means including an internal web site, semiannual reports, newsletters, and workshops. Access to this trend information gives product developers the ability to anticipate requirements and may prevent possible delays in time-to-market, a critical parameter for the company (Xerox, 1997a, p. 6).

Volvo has also developed analytic tools to aid designers with design-for-environment. It employs a planning template in advanced engineering; EPS, a life-cycle analysis tool; MOTIV, a chemical database; design checklists; design guidelines; and manuals.

To help integrate environmental concerns into advanced engineering, Volvo has developed a template to structure the planning process. For each department—exterior, body, chassis, engine, transmission, styling, interior, etc.—environmental and engineering personnel walk through several aspects of the product—resource use, clean production, emissions during use, materials use, noise, recyclability—and determine what a “green” system might look like. They determine the relationships between system characteristics and these environmental characteristics. Having established the baseline characteristics, they identify the technological barriers to improvement. Technology investments to eliminate these barriers are planned over a 10-year horizon. The actual investments are made

experience helps product stewards understand the ultimate fate of materials and recycling costs.

based on market demands and anticipated market introduction by competitors. (See Figure A.3 for the planning template.)

The Environmental Priorities Strategies (EPS) is a life-cycle assessment tool used by design engineers at Volvo Car Corporation. Industry participants and research scientists collaborated on EPS development and in the process established several ground rules or guiding principles to ensure that EPS would be useful to and employable by design engineers while also meeting the tenets of sustainability and considering all environmental effects appropriately.¹⁴ Industry designers were particularly concerned about creating a tool that was quick to use and could be incorporated into multi-dimensional product design analyses. Although the EPS model and database are still under development, Volvo analysts are comfortable that results are accurate enough at present for decisionmaking if a specialist operates the model and interprets the results in the context of business decisions.

In addition, Volvo finds the structure of the system useful for thinking through all the environmental issues associated with product design—for determining high-leverage areas for investment and additional study, as well as for educating product designers. One of the ways in which Volvo finds EPS useful is for developing an overall environmental strategy. Because the environmental issues associated with the automobile life-cycle are complex and wide reaching, it is very useful to have a method for structuring and assessing the myriad sets of issues. The structure of the EPS system and the framework of the resulting analyses help the company organize environmental goals, look for high-leverage areas, and communicate information to managers, designers, and customers alike. The managers and designers can then focus their analyses and investments on those areas that provide the greatest leverage to environmental issues and may constrain automobile design in the future. The analyses provide a foundation and rationale for communicating

¹⁴Allenby (1996) characterized the three extant life-cycle assessment methods into the following categories: high-level qualitative matrixes (AT&T/Lucent Technologies' approach), which are primarily good for internal use, involve lots of judgment, and are not good to communicate to external audiences; quantitative methods with detail on values (EPS), which causes problems when costs or values are unknown; and the thorough and detailed approach (SETAC), which can get overly complex and detailed given data availability and large uncertainties.

environmental impacts of automobile design both within the corporation (to business managers and decisionmakers) and outside (to policymakers, customers, and the public). The other primary way in which EPS is used by Volvo to implement design-for-environment is to educate designers about environmental issues. The comprehensive set of environmental issues and the relationship of design to environmental impact in EPS are used to communicate and train designers to think about the long-term and the life-cycle environmental effects of their design, material, and process choices.

Other tools help designers with chemical selection and use. These include lists of banned chemicals and those that might be banned, as well as a database identifying all chemicals used throughout the company. The blacklist is a set of chemicals prohibited by Volvo for its own operations as well as for those of its suppliers. The list is a compilation of substances banned in countries around the world, as well as those that Volvo has determined to be too risky to use. The associated gray list includes those chemicals that Volvo is phasing out. These lists are available to all Volvo employees, including design engineers and not just the EH&S specialists, so that all employees can easily avoid using these chemicals in the first place. In addition to the black and gray lists, MOTIV is a corporate database of 4,000 chemical products used in all products and processes in all Volvo companies. The recipe for each chemical must be submitted by its supplier to Volvo or the product is not purchased. This sensitive information is accessible only to a handful of users at each company. MOTIV was developed to help minimize the use of environmentally hazardous substances and to simplify the specification of various chemicals. The overall database can easily be consulted to ensure that chemicals on the blacklist are not being employed or to determine the locations of particular chemicals in use. Designers can use it to focus on those already in use and to see which chemicals are being phased out by the corporation. Because this information is readily accessible, it can be used both to resolve short-term emergencies and to assist in product and process chemical choices. "Environmental questions have to be answered directly in product development. These are the best people to make the decisions." (Allenby, 1996.) As a result of having this information generally available, the number of chemical products purchased by Volvo per year

was halved, from 800 to 400 (AB Volvo, 1994), and the use of several substances was discontinued (AB Volvo, 1995).

Accounting Techniques

The accounting systems and techniques applicable to design-for-environment aim to identify the total cost to the company of its environmental activities as related to particular design features, such as materials use. In some cases, they seek to include some of the externalities for particular environmental attributes. Many employ or seek to employ an activity-based costing approach. Volvo has this system in place.

Systems Engineering and Program Planning

Program planning and project engineering techniques can be used to help designers with environmental decisionmaking. For instance, Texas Instruments has modified more than 35 product and process development tasks to incorporate environmental decisionmaking (Ufford and McKelvey, 1996, p. 92). Both Texas Instruments and Xerox incorporate environmental criteria into their design review processes.

Tool Development and Deployment

Just as important as *which* analytic technique is chosen is *how* the analytic tool is developed and integrated into design processes. Studies of Volvo, Lucent Technologies, and others suggest that it is more important to get the design-for-environment process started than to have analytic tools that are precise to the *n*th degree. Moreover, the most important aspect of implementing new technical processes and tools is to treat and manage the implementation process as an innovation itself, rather than as "the mere execution of a plan." Using the analogy of new product development for the implementation of new processes and tools means that the customers are the internal organizations that will employ the new practices. It follows that successful implementation will involve users to develop the new process or tool design and create buy-in. As much attention should be given to selecting experimental users as is

given to the specific tool or process design. In particular, experimental users should be interested and willing. They should also possess a knowledge base representative of the user group. Co-development is a very useful way of incorporating user input because both users and developers are forced to share problem-solving and hence responsibility for the success of implementation. Furthermore, mutual understanding is garnered at the group level rather than the individual level. Moreover, mutual adaptation, where the new tool is influenced by the users at the same time that user processes are affected by the tool, is more often associated with co-development. This iterative process of introducing new concepts with the requisite organizational change is more easily addressed with co-development. This can also help mitigate the negative affects from uncontrolled change (Leonard-Barton, 1996). Staff members at Lucent Technologies also suggest that it is important to have relationships with other firms, academic institutions, national labs, and government at all levels to integrate the latest thinking into the company's programs (Dambach and Allenby, 1995, p. 61).

Thus, training, analytic tools and methods, and other design aids are important to design-for-environment programs because they support the individual decisionmaker who ultimately determines whether or not the program is successful. The following are lessons from the literature and case study companies regarding training and analytic tools:

- Training increases the individual's awareness of environmental issues and develops new skills or competencies.
- Training seeks to influence behavioral change by improving the individual decisionmaker's understanding of environmental issues and attitudes toward the environment.
- Analytic tools facilitate and guide decisionmaking by conveying timely information, encoding priorities, and providing analytic structure.
- Analytic techniques that consider environmental issues must be incorporated into existing product-realization processes in a way that does not add time or complexity.

- Tools and methods that are co-developed with the functional experts responsible for employing them are more likely to be implemented.
- Methods and techniques should be simple at first. Do not overburden a fledgling design-for-environment program with extensive data requirements. Plan to refine data and methods as the design-for-environment processes mature. Learn with time.
- An organization should continually develop and maintain external relationships in order to incorporate new thinking and techniques. This is generally true for the entire design-for-environment program as well.
- A mixture of quantitative and qualitative decision aids is required for informing design decisions.

In the past, DoD has sponsored environmental cost modeling and design guidelines, and the department has a long history of employing systems analysis in its decisionmaking. Recently it has highlighted the importance of simulation and modeling to its ability to practice pollution prevention in acquisition (Gansler, 1998a).

Because DoD designs and procures complex systems through an acquisition process that involves large organizations, environmental awareness education and specialized training coupled with decision aids and analytic tools are especially important. They encode priorities, guide individuals, and focus the decisionmaking processes. Because of weapon systems' complexity, the structure provided by these analytic tools facilitates the complex decisionmaking process.

Perhaps the most important lessons that can be applied to DoD and whichever series of analysis tools it develops are that it must have organizations and processes in place to utilize the information in decisionmaking. The analytic tools can be qualitative at first, and the organizations responsible for employing them must be active in their development.

CONCLUSIONS AND RECOMMENDATIONS

The case studies clearly show that a successful design-for-environment program has many different elements or building blocks. To successfully incorporate these issues into design, several needs—ranging from organization bridges to information—must be addressed. For example, a particular analysis may be thorough and insightful, but if the organizational links to act on the information generated do not exist, improvement will not occur. Strategic planning is meaningless unless the individuals in the organization responsible for actuating the plan understand it and have the skills and capability to implement it.

The Department of Defense has an active program to incorporate environmental issues into the acquisition process. This is one of three focus areas for the department's recent Environmental Security Strategic Plan.¹ It seeks to further this objective by emphasizing five areas. The first area is to limit bureaucracy by streamlining rules and regulations. Two, emphasize life-cycle cost reduction, a major rationale for pollution prevention. Three, insert EH&S issues into integrated product teams to expand problem ownership and problem-solving capability. Four, develop and introduce new technologies that have positive environmental attributes and reduce cost. Five, employ modeling and simulation to the maximum extent practical to help anticipate issues and to seek solutions cost-effectively (Goodman, 1997).

¹The other two areas are partnerships—with regulatory agencies, tribes, NGOs, and communities—and international activity—through military cooperation, joint training, and leading global trends.

Several initiatives have been undertaken by the department in recent years in light of this strategic focus. For example, recent changes made to the acquisition regulation, 5000.2, incorporate a more comprehensive view of the environmental issues that includes cost estimates of the weapon system life-cycle, including dismantling and disposal. Program managers are trained to deal with environmental issues at the DSMC. Leading installations, programs, and individuals are recognized at the Secretary of Defense's Environmental Security Awards, including weapon system acquisition. Life-cycle cost models are under development. And a senior-level tri-service committee, the JG-APP, has been created to remove barriers to pollution prevention across weapon systems and at contractor facilities.

Nevertheless, several ideas, based on the literature review and case studies, could enhance and strengthen the existing program. Suggestions are as follows:

Vision and strategy. Engage the other functional organizations—others within acquisition and technology, installations management, logistics, and other operational organizations within OSD and the services—to develop a new environmental policy for the department. While the department has an environmental policy with content on a par with leading commercial companies, implementation of this policy may be facilitated if it belongs to the organizations that are ultimately responsible, such as other offices in acquisition and technology, installations management, logistics—in both OSD and the services. As with the debate that Volvo's corporate managers engaged in while revising its environmental policy, this would give a much richer understanding and awareness of the policy's intent and nuances not only to the organizations within DoD ownership but also to those ultimately responsible for implementing the policy. Additional detail or guidelines on policy implementation could also be developed at this time, much as Volvo and Hewlett-Packard began with a broad statement and then provided additional guidance on how it will be operationalized.

Also, the department could focus analyses by identifying the strategic environmental issues for each weapon system type using the revised environmental policy and issues raised in its development. It would require some study of previous acquisition programs to identify the major environmental issues and cost drivers to build a template of

major environmental effects by weapon system type. These actions would strengthen the weapon system program offices' ability to build on prior experience and would focus analyses and decisions on high-priority areas. They would also help focus the development of design guidelines and metrics. Program office planning could then be much more focused, and this would improve the probability that environmental issues will be integrated into program planning and not viewed as a paper exercise. Improvements over time within and among programs could also then be tracked more easily.

Organizational. Identify environmental product design stewards within the SPO and contractor design team to champion environmental management within the program and to serve as links to the rest of the department on such issues. Develop mechanisms—e.g., listings on DENIX or the Acquisition and Technology home page, or workshops—that augment the networking of the environmental office security staff for communicating and disseminating information to, from, and between these champions. This is how Hewlett-Packard uses its Fountainhead database of corporate environmental policies, design practices, and points-of-contact information. Another organizational tactic would be to use the environmental security office staff to disseminate information and catalyze action by scheduling routine meetings with these individuals to discuss the environmental issues on the program, metrics, technology needs, contractor issues, information needs, etc., much as the Volvo Environmental Competence Center operates. Establish organizational links between designers and the JG-APP so that the designers benefit from operators' and maintainers' interests and priorities to ensure that life-cycle costs and impacts are minimized to the extent practicable. Recall that customer preferences have been strong motivators for private sector design-for-environment programs. Provide a prioritized overview of the issues facing environmental stewards on an annual basis to the DAB and the JG-APP so that strategies can be refined, investment priorities can be determined, and organizational or other barriers can be addressed at a senior level.

Management metrics and goals. Based on the weapon system-specific strategies, use the product stewards and environmental security staff to develop a generic list of metrics by weapon system type. For aircraft this could include mean time between main-

tenance actions, number of hazardous materials required for maintenance, etc. Link and relate the strategic environmental issues to traditional weapon system acquisition program and system performance metrics (such as those reported in the Selected Acquisition Reports, as well as more detailed measures reported in DAB reviews, etc.) as much as possible. For example, relate environmental issues of strategic importance to measures of fuel efficiency, system reliability and maintainability, system service life, and cost. As discovered in the literature and case studies, this is an important and perhaps difficult process. However, it is necessary for individual decisionmakers and designers if they are to understand how their decisions influence environmental management. Develop new measures for the significant environmental issues that may not relate to traditional measures. Require the program manager, the program office, and contractor environmental stewards to select the metrics that make the most sense for the program and establish program goals that improve on previous systems of the same type or class. Link the goal-setting activity to the JG-APP just as Volvo gathers information from its service and sales centers to ensure that operators' and maintainers' (or customers') operational experiences and priorities are addressed.

Use the stewards and the environmental security staff to track progress toward these goals. Importantly, augment the current program review process with periodic environmental audits using a structured procedure to ensure that they are adequately implementing the environmental policy and moving toward goals. And report all findings to the Deputy Under Secretary of Defense for Environmental Security and the Under Secretary for Acquisition and Technology to get high-level visibility and support. In the Volvo case, the structured audit or review process ensured that managers evaluated their program in a rigorous and consistent manner. High-level visibility served to create competition.

Suppliers. The relationship with suppliers, or defense contractors, is a very important area to DoD because much of the design work is performed by them. Unfortunately, the literature and case studies provide minimal insight into how to improve interaction. Private sector companies have been clear and direct in their environmental requirements for suppliers; even when their buyer position is not as dominant as the DoD position. If these issues are important to DoD,

and this importance is communicated, its suppliers will respond. Identifying environmental stewards within both organizations will improve awareness of environmental issues and aid joint problem-solving. Shared program environmental metrics may focus management attention and supporting analyses.

Training and analytic tools. Because DoD designs and procures complex systems through an acquisition process that involves large organizations, environmental awareness education and specialized training coupled with design aids and analytic tools are important facilitators for improved decisionmaking. Moreover, given the large number of individuals involved in these processes, training will increase overall awareness of environmental impacts and provide a common level of understanding of such issues. Because an extensive survey of DoD's activities in this area was beyond the scope of the study, detailed recommendations on specific analytic tools cannot be provided (although those more familiar with DoD activities may easily use the information provided in Chapter Four to do this). However, there are lessons for DoD regardless of the specific tools under development.

Perhaps the most important lesson is that analysis tools are useless if the organizations and processes are not in place to exploit the information generated by them. We see from the Volvo case study that the corporation is very involved in the development of the Environmental Priorities Strategies life-cycle analysis system. It uses the system even though it recognizes that the data could be improved and refined. The literature also supports this recommendation.

Because these tools must support real-time decisionmaking and incorporate detailed knowledge of systems design practices, it helps to co-develop analysis tools and information systems with the stewards and key functional experts from the SPO, defense contractors, and other organizations in DoD. These techniques can be approximate at first and refined as experience with them grows.

VOLVO CASE STUDY: DRIVING TOWARD GREEN

Interviews with personnel in the Volvo Car Corporation in late 1996 and late 1997 are the primary information source for this case study because written information on its design-for-environment program is scarce. Company brochures were also used when applicable. Please note that case studies are snapshots of an organization. Since these interviews were performed, the details of the program have most certainly evolved. However, subsequent communications with Volvo personnel have indicated that while the details may have changed, the messages are largely the same.

OBSERVATIONS ON VOLVO

There are many interesting and enlightening aspects to environmental management and design-for-environment at AB Volvo and Volvo Car Corporation. Perhaps most important, Volvo is a corporation that recognizes the strategic advantage of incorporating environmental issues into its corporate culture, business processes, and, therefore, business decisions. Volvo believes that consideration of environmental issues can lead to a competitive advantage. Its environmental policy explicitly states that making money is its primary business and only if Volvo remains financially viable can it help the environment; that environmental programs can contribute to long-term profitability and economic growth; and that environmental issues should be treated aggressively within the time and scope constraints of long-term profitability. Volvo sees a dynamic business environment in which competitive advantage is gained through first-mover advantage, process control, and continuous improvement. It

evaluates global trends in regulations and incorporates these into the advanced development and product design processes. Within the higher-end automobile market, Volvo anticipates a growing consumer market for “green” products and is setting up organizational processes with its marketing organizations, dealerships, and design groups to collect and manage the information needed to offer such products.

The Volvo environmental policy

- clearly articulates corporate environmental objectives for internal and external communication
- states that proactive management of environmental issues is one factor contributing to strategic advantage
- was developed by senior functional experts, not the environmental managers.

The environmental policy shapes all environmental organizational structures and goals, management processes, and design activities. It is the glue that cements the different parts of the corporation, namely the companies and the units within the companies, together. Because the companies have different resources and face different market pressures, debate is an important factor in the successful implementation of a new policy. Debate builds consensus and commitment to the policy. The companies and units are then free to operationalize the policy in ways consistent with their unique resources, products, and market pressures.

Organizationally, the environmental program is fairly decentralized and relies on communication in all directions. Each level gathers information and solves problems. While consensus building is important for policy development, the corporate management processes of goal-setting and audits illustrate that competition and visibility are used to drive policy implementation. The key elements of Volvo’s environmental organizational structure are

- a high degree of senior, line management participation
- environmental policy boards with decisionmaking authority

- parallel organizational structures at corporate and company levels to aid the flow of information.

The corporate Environmental Board and Environmental Council address issues of corporatewide importance to ensure consistency and appropriate action and to drive action. Key processes are

- decentralized goal-setting, with corporate oversight, to reinforce ownership and stimulate action and improvement
- audits to ensure that corporate standards and environmental policy are met by the companies.

Volvo management is pragmatic. The Volvo companies have real constraints and therefore must constantly balance competing interests. They have established a robust process to attain clearly articulated objectives. Volvo searches for “win-win” solutions to environmental problems in a structured way to focus management attention on long-term strategy and ensure that investments made are the most effective means of progress. The process is not rigid, however; it is flexible, strives for success, and learns from failures.

Volvo Car Corporation has approached product design from many dimensions. At VCC, environmental issues are part of strategic planning, but investments are made on competitive grounds within everyday financial constraints. Moreover, environmental criteria compete with many others in new product design and development. Goal-setting is an important part of implementation. Structured goals provide strategic focus. They help to relate specific activities to company goals and facilitate improvement. Clear priorities in this case—business, safety, quality, and environment—make decisions easier. Market interest and company strategy motivate individuals to try to meet and improve goals. The Environmental Competence Center personnel actively inform and remind others of these motivations.¹

¹Since completion of this case study, VCC has decided to reorganize the environmental experts and the Environmental Competence Center. Originally it was felt that the environmental staff should be centralized because they were co-developing new skills and analytic tools with the functional experts. Now that the new skills have been developed and these activities have become operationalized, the Environmental Competence Center staff will be dispersed, in small groups (not singly), to the func-

The Environmental Competence Center personnel interact with design organizations at two levels. At the manager level, the Director of the Environmental Competence Center builds political support and visibility for environmental goals. At the working level, individual relationships increase awareness and support for the goals. They are also instrumental in helping designers develop new competencies. Individual designers are better equipped to think about long-term impacts of their decisions by working through recycling issues and environmental life-cycle assessments. *Individual competence is especially important, because new product design is characterized by decentralized decisionmaking and many design trade-offs.*

Another major aspect of design-for-environment implementation is the development of analytic tools and specialized competencies. Environmental awareness training addresses both individual values and awareness. Analytic tools facilitate environmental analyses and codify values for the analysis process. These are particularly important to design-for-environment implementation because ultimately the environmental profile of a product is determined by many cumulative decisions made by design engineers and others alike, not the environmental experts. Environmental Priorities Strategies (EPS), a life-cycle analysis tool, is used to build new competencies among design engineers. The EPS life-cycle view and the analysis framework also link the various goals and targets that VCC has established. MOTIV, a chemical database, makes information available to the design engineer and not just the EH&S specialists. This has helped reduce the number of chemicals used at AB Volvo. Volvo Dialogue, a general environmental training program, increases the understanding and appreciation of every Volvo employee. It seeks change through education. Finally, education provides a common vocabulary for all employees.

Finally, *implementation of change takes time*. The first AB Volvo environmental policy was issued in 1983. In 1994 the policy was revised for the second time to emphasize the relevance of environmental issues to strategic direction and profitability. In 1997–1998 the policy is being revised again. Expectations are that it will take six

tional areas, such as production, recycling, and product development. While the Environmental Competence Center will have a smaller staff, the link to strategic planning will become stronger (Fräjdin Hellqvist, 1997).

years, to 2000, to develop a fully operational environmental management system at all AB Volvo companies and units. Another example is the life-cycle model used by Volvo Car Corporation. It has been five years in development, and it is still not considered a mature tool. These time lines highlight the challenge to change and the realistic expectations given business constraints.

ENVIRONMENTAL MANAGEMENT AND INTEGRATION INTO PRODUCT REALIZATION

AB Volvo Overview

AB Volvo was founded in 1927. Six companies, responsible for a series of product lines, make up AB Volvo or the Volvo Group. These companies are Volvo Car Corporation, Volvo Truck Corporation, Volvo Bus Corporation, Volvo Penta Corporation (marine and industrial engines), Volvo Construction Equipment Corporation, and Volvo Aero Corporation (aircraft engines). The entire corporation, AB Volvo, has 38 production facilities in 23 countries that service 100 markets worldwide. The Swedish market accounts for less than 10 percent of Volvo's sales (AB Volvo, 1995).

The Volvo Car Corporation has approximately 30,000 employees worldwide (dealerships add roughly 40,000 personnel, and major suppliers are an additional 2,000, for a total of approximately 70,000 personnel associated with VCC). In 1995, sales reached SKr154,496 million (approximately \$20 billion U.S.) for 374,600 cars (for comparison, Volvo Truck Corporation sold 76,500 trucks and Volvo Bus Corporation sold 6,830 buses in 1995) (AB Volvo, 1995). According to our interviewees, Volvo Car Corporation is facing competitive pressure. As a result, they are trying to reorient corporate culture toward cost reduction, innovative design approaches, and problem-solving.

While corporate core values and the environmental policy are common to all the Volvo companies, specific environmental policy implementation does vary. Policy implementation at Volvo Car Corporation, particularly as it relates to design-for-environment, is described in this case study. When information on the diversity of approaches is available, it is presented.

Why Design?

Control of product and process design is one mechanism for seeking cost-effective environmental management. Available estimates range between 70 percent and 80 percent of the product life-cycle costs and are determined during design. So changes in design can cost-effectively leverage effects, both upstream and downstream (Office of Technical Assessment, 1992; Kainz, Moeser, and Simpson, 1995). Volvo personnel also realize that the design phase offers high leverage over the product life-cycle costs and risk reduction and they seek to identify and invest in the most cost-effective technologies to achieve desired environmental performance levels.

Environmental issues are not new to Volvo, and it has taken a life-cycle view of its products for around 10 years. Emission controls have existed since they were first introduced in California in 1965 (AB Volvo, 1989, p. 6). The first serious design issue to arise from environmental concerns was the catalytic converter, which was first introduced by Volvo in 1976. Over the years, catalytic converters have become increasingly capable, reducing an ever broader range of harmful emissions. By aiming beyond compliance and striving for continuous improvement, companies can mitigate the uncertainty associated with regulatory change on the margin and are equipped to negotiate on proposed future regulation. As described later, because of its understanding of automobile life-cycle issues, Volvo was able to successfully suggest changes to the proposed Swedish automobile recycling law to include more credit for energy recovery.²

The other dimension to product design at Volvo is driven by market interest as opposed to cost reduction. Volvo detects growing demand in its target market (the higher end) for a "greener" product.³ One of AB Volvo's goals established by the AB Volvo Environ-

²The Dutch, considered leaders in sustainability thinking, promote environmentally conscious design as an effective means for chain management. Chain management is the management of the environmental impacts of all players in a product's value chain as a whole, rather than as individuals. They see chain management, achieved in part through product design, as one way of getting additional environmental improvements and moving toward a sustainable society (Vermeulen, Kok, and Cramer, 1995).

³VCC views its product niche as the higher-end automobile emphasizing safety and quality (sometimes referred to as durability).

mental Board in 1993 is: "To ensure that at least one variant per model family in the VCC range meets the requirements of the highest environmental class in the relevant European incentive system."⁴ Volvo's CEO, Sören Gyll, has emphasized this in his statements and has called for Volvo officials to build the case for such a profile in its decisions about process and product design and Volvo-demonstrated performance. VCC is beginning to develop an environmental profile for its products, due in part to the desire of dealerships to communicate Volvo's products' environmental attributes to customers.

The remainder of this appendix is organized as follows. Because AB Volvo's corporate environmental policy provides the overall framework for the environmental organization and management processes, the policy is described next. Then the organizational elements that operationalize the policy are explained, emphasizing Volvo Car Corporation's structure. Following this discussion, key management processes and their relevance to design-for-environment activities are described. In the second section, a particularly important design aid, the Environmental Priorities Strategies, is described in greater detail. The third section summarizes the findings of the case study. The fourth section presents Volvo's high-level environmental policy goals.

Volvo Core Values and Environmental Policy Set the Stage for Implementation

AB Volvo aims to elevate environment to the level of its primary core values—safety and quality—and to integrate environmental issues into its way of doing business to the same extent.⁵ Yet, managers are fully aware this will take time and persistence. They point to safety, which has been a core value at AB Volvo since the corporation was begun in 1927.

⁴AB Volvo Goals and Action Programme as reported in *AB Volvo Environmental Report 1995*. Similar goals are stated for Volvo Truck and Volvo Penta (marine) companies.

⁵Numerous studies have shown that it is easier to implement organizational change if the change does not conflict with corporate core values.

Its environmental policy provides the overall framework for Volvo's environmental organization and management processes.⁶ The environmental policy is the most significant environmental message from corporate leaders, both CEOs and line managers, and it clearly articulates AB Volvo's views toward environmental issues for both internal and external audiences.⁷ The environmental policy is common to the different parts of the corporation, namely the companies and the units within the companies. The companies and units are then free to operationalize the policy in ways consistent with their unique resources, products, and market pressures. Because the policy shapes all environmental organizational structures and goals, management processes, and design activities, understanding the policy and its derivation is critical to gaining insight into design-for-environment implementation.

Because the companies have different resources and face different market pressures, debate is important in the successful implementation of a new policy. From their experience, Volvo personnel have observed that debate builds consensus and commitment to the policy. It also contributes to successful implementation because managers internalize their understanding of the policy's meaning and intent through the debate (Fräjdin Hellqvist, 1996b). The environmental policy is a one-page document originally formulated in 1983, with origins dating to 1972. There was a major revision in 1989, which was debated by top executives from each company in an environmental council meeting (described below). Managers felt this was a very useful process, as the debate built consensus and ensured in-depth understanding by all executives, both environmental and line. In 1994, a minor change was made to the policy to comply with Eco-Management and Auditing Scheme (EMAS) requirements. In

⁶The commitment to environmental issues is exemplified in the actions of its leaders, who have made statements, spent management time, and approved investments in favor of the environment. Since the company's 1927 inception, Volvo leaders have displayed strong social commitments, and these easily extend to include environmental issues. AB Volvo CEO Pehr Gyllenhammar expanded the corporation's social commitments' scope beyond product safety to include workplace issues (Rothenberg and Maxwell, 1993).

⁷Volvo is one of the first industrial manufacturing corporations in the world to adopt a formal environmental policy (Rothenberg and Maxwell, p. 3). To reach a wider external audience, AB Volvo has been publishing an annual environmental report since 1991.

contrast to the previous revision, this change was not debated. As a result, many feel that these changes were not internalized by managers. The environmental policy was revised in the 1997–1998 time frame. These changes have been discussed and deeply debated by line management from each of the companies. While the new policy has not been officially released, analysts anticipate that the changes will be major without altering objectives. However, its guidance will be sharpened and will more clearly enumerate what needs to be done to implement it (Fräjdin Hellqvist, 1997).

Over time, the content of the environmental policy has changed as well. Initially it was compliance focused; later Volvo management realized there was a stronger connection to business decisions.⁸ The current AB Volvo Environmental Policy addresses the broad range of effects that the transportation system has on the environment. This includes land, sea, and air transport's relationship to the environment (e.g., natural resource use, land use, air quality, water quality, all wastes, and noise). The environmental policy explicitly states that:

⁸This evolution was brought on by a series of events in the mid- to late-1980s. For one, there was a worldwide trend increasing corporate liability for environmental damages. Sweden was also phasing out CFCs on an aggressive schedule. Moreover, environmental groups criticized Volvo CEO Pehr Gyllenhammar's active support of the Scan Link, a road and railroad from Oslo to Denmark. Swedish environmental groups reacted strongly to expansion of the Torslanda paint shop. The Torslanda plant expansion in particular was a turning point in Volvo's view toward compliance. Environmental NGOs thought the company could do better and protested the plant expansion. The Minister of Environment called Volvo the greatest polluter on earth. As a result, Volvo invested in cleaning treatments and rotors to filter the emissions of VOCs. Ironically, because this involved cleaning air through sand at an elevated temperature, Volvo traded a VOC problem for a CO₂ problem. The expenses associated with this change were taken out of profit (SKr1,000 to SKr2,000 per car), although they did contribute to product quality. In the new sport coupe, C-70, Volvo will avoid this problem altogether by using powder-based paints.

This experience drove home to Volvo management the realization that, if environmental issues were treated in a proactive manner, more cost-effective solutions would be found. Volvo also sees the situation as an example of when reactionary actions can lead to detrimental environmental effects. They realized that taking control of environmental issues, establishing goals and responsibilities, and communicating actions to stakeholders could lead to more cost-effective or "win-win" solutions and competitive advantage. The AB Volvo CEO and the board of directors were tired of the criticisms. They invested \$50 million of their own stock to become world-class environmental stewards (Fräjdin Hellqvist, 1996b; Rothenberg and Maxwell, 1993).

- Making money is Volvo's primary business and only if it makes money can it use the money to help the environment.
- Environmental programs can contribute to long-term profitability and economic growth of the corporation.
- Environmental issues should be treated aggressively within the time and scope constraints of long-term profitability. (AB Volvo, 1994a.)

The specific environmental policy elements recognize the need for a comprehensive strategy, to include R&D, product development, and manufacturing; the use of sound materials (especially those that are recyclable); a broad focus on transportation systems; the need to comply with comparable laws worldwide; a similar level of care by suppliers; and factual and open information on the impact of company operations (AB Volvo, 1994a).

The environmental policy is implemented within the context of a business perspective. In other words, it is implemented with full recognition that Volvo is and should be principally geared toward making money. Only within this context can Volvo then discuss minimizing environmental impacts. Another important feature of the policy is the explicit recognition that proper treatment of environmental "performance" can lead to competitive advantage. Thus, environmental issues are treated as other strategic business issues are.⁹

Even so, Volvo has found that actually integrating environmental issues with business decisionmaking is difficult because environmental issues touch on individuals' core values and ethics. And these can vary among individual decisionmakers. If environmental effects can be put into monetary terms, it is easier to get personnel to respond. For example, Volvo can easily make the business case for

⁹Michael Porter suggests that companies can find many "win-win" solutions to both economic and environmental objectives. He presents cases to show that treating environmental issues in corporate strategy to include resource efficiency and green consumerism will benefit the environment and will lead to a competitive advantage for the company. (Porter and van der Linde, 1995, pp. 120–134.) In another *Harvard Business Review* article, Noah Walley and Bradley Whitehead suggest that incorporating environmental issues into business management is not so simple. Their comments will be addressed below.

recycling. If Volvo doesn't meet the requirements of the Swedish recycling law, it must pay a fine, which may mean raising the price of the automobile or earning smaller profits.¹⁰

The environmental policy statement is the only common environmental policy across the Volvo companies. The specific strategies and goals are left to the companies to develop independently, although there are some worldwide standards and consistent processes. At this point, policy implementation varies across the Volvo companies, in terms of both progress toward a fully established management system and their approaches to implementation. It is expected that generally greater commonality will exist among the production-oriented goals than among the product-oriented ones because products vary.

The following are important implementation lessons regarding the Volvo environmental policy:

- The policy clearly articulates corporate environmental objectives for internal and external communication. It is the common thread linking all Volvo companies.
- The policy objectives are stated in business terms and see the environment as one factor contributing to strategic advantage.
- The policy was developed by senior functional experts, not the environmental managers. Active engagement by managers in policy development was instrumental in ensuring greater awareness and buy-in by line managers.

Volvo companies are actively setting up organizations and processes to operationalize the corporate policy. The next sections discuss the environmental organizational structure at the corporate and company level, focusing on Volvo Car Corporation. Note, the way change is implemented is just as important as the particular changes made. Insights into both sets of issues are provided.

¹⁰The Swedish recycling law requires 85 percent of the automobile to be recyclable by 2002.

Environmental Organizations Are the Most Important Element of Policy Implementation

Implementation of the broad environmental policy guidelines is facilitated at the corporate level through the AB Volvo Environmental Board, a decisionmaking body, and the AB Volvo Environmental Council, which supports the board. Overall, environmental organizations at AB Volvo and the constituent companies are a combination of line functions, working groups, project groups, and networks, emphasizing inclusion of activities within the appropriate line functions, especially at the "local" level.

Each company is responsible for developing its own organization to pursue corporate policy. Volvo Car Corporation (VCC) believes that it will be essential to have a clear organizational structure in place before the public, regulators, and environmental NGOs take the company seriously. VCC found that creating the appropriate organizational elements is the most important step in policy implementation—"you must build the bridge before you can cross it." (Fräjdin Hellqvist, 1996a.) VCC aims to create an organization that develops its own goals and strategies by implementing Volvo's environmental management systems (VEMS) throughout VCC.

AB Volvo Environmental Organization

The overall governing body for environmental issues at AB Volvo is the AB Volvo Environmental Board. Members of the AB Volvo Environmental Board are the top vice presidents for each company. The specific vice president represented on the corporate board varies from company to company. However, generally the line functions represented are related to the corporation's core values of safety and quality. For example, the VCC representatives to the AB Volvo Environmental Board are the car company's senior vice president and the marketing director. Some of the line-oriented members on the AB Volvo Environmental Board also sit on the Corporate Executive Committee, which is the highest corporate committee of line vice presidents at AB Volvo. The corporate Environmental Board makes decisions on environmental issues of major strategic importance to the entire corporation. This includes policy decisions, common guidelines and coordination, other corporatwide matters,

and audits. This is a decisionmaking board that receives input from the corporate Environmental Council. There also are working groups on specific corporatewide issues that report to the corporate Environmental Board.

Environmental managers of the various companies serve on the corporate Environmental Council, which proposes policy and advises the decisionmaking Environmental Board. The seven environmental managers on the council come from corporate AB Volvo and the six companies: Volvo Car Corporation, Volvo Truck Corporation, Volvo Bus Corporation, Volvo Penta Corporation, Volvo Construction Equipment Corporation, and Volvo Aero Corporation. This structure is shown in Figure A.1.

The organizational elements common to all Volvo companies are environmental boards and coordinators. The environmental boards (at all other levels the environmental boards are equivalent to the council at the corporate level) are established for the overall corporation, for each company in the Volvo Group, and for each "main

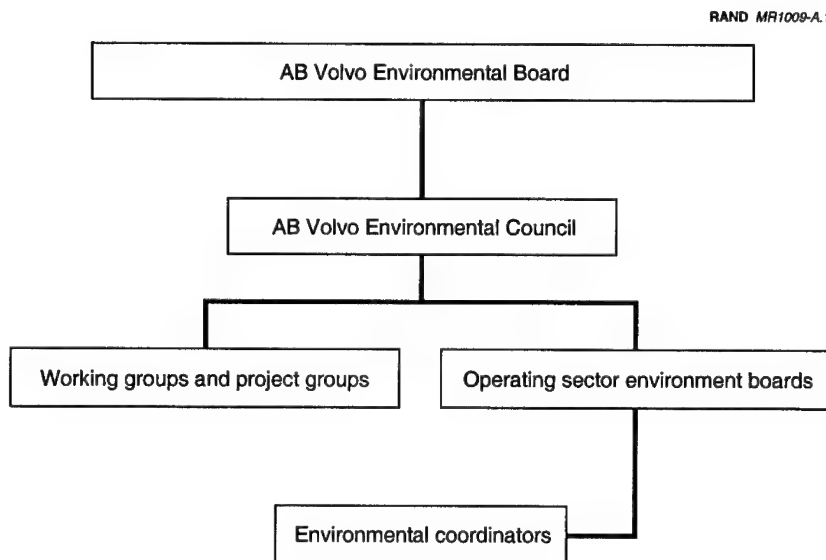


Figure A.1—Volvo Environmental Organizational Structure

unit" within a company (which may be a facility).¹¹ An environmental coordinator for each company and for each "main unit" directs and evaluates environmental programs at the local level. These coordinators are selected by the company or unit managers. This parallel organizational structure facilitates information flow both up and down the links as well as across them and aids decision-making at the local level.

The corporate Environmental Board uses a number of key mechanisms to drive action. They address issues of mutual concern, challenge the companies with goals, and monitor progress and create visibility with audits. Some of these mechanisms are part of the specific processes that make up the Volvo Environmental Management System, and these are described in greater detail below. However, to show how the corporate board and council work with the companies, we present an example of developing an overall corporate policy on a specific environmental issue.

If the corporate Environmental Board seeks to develop a corporate policy, it works through the Environmental Council. As mentioned, the AB Volvo Environmental Council handles special corporatewide issues, such as global change, particulate matter, or recycling and plastics. An individual council member is responsible for collecting information on a specific topic and for developing a draft policy. For example, on the global change issue, an Environmental Council member gathers information from both internal and external experts and shares this with the Environmental Council and others, as appropriate.¹² Scientists' and experts' views are sought on the specific issue, while the Agenda 21 process¹³ provides benchmarking information on other companies' activities.¹⁴ (On the global change

¹¹It is confusing, but councils are called boards at the company level, and the corporate level is the only one that has two groups. For all other levels, company and unit, the "board" and "council" are the same organization. The corporate board coordinates policy and programs with the various companies through the company environmental boards.

¹²External experts also can be another "messenger" to the corporate line management, which at times can add credibility to the point being made.

¹³Agenda 21 originated at the 1992 Earth Summit at Rio de Janeiro to help communities work locally to preserve future environmental quality of life.

¹⁴In contrast, the Dow environmental advisory board includes environmental experts from environmental NGOs and elsewhere. It is a forum that meets regularly to provide

issue, renowned scientists on both sides of the issue have been to Volvo.)¹⁵ Internally, the council member discusses the issue with the various company vice presidents. Their responses are tallied on a scorecard and reported to the board. Sharing these responses with the board creates a little competition between companies and encourages thoughtful responses on the part of the company vice presidents. For example, coordinating a response with the companies and the AB Volvo Board on the global change issue has been ongoing for approximately one year. The Environmental Council then presents a proposed policy and an implementation plan to the corporate Environmental Board for a decision. These decisions are then implemented through the environmental boards and coordinators at each of the companies and their business units.

Generally speaking, Volvo recognizes that associating power with an issue is a way of getting people's attention and ensuring that they take the issue seriously.¹⁶ For example, the AB Volvo's environmental vice president is one of the 60 top line managers corporatewide.

So, organizationally, the environmental program is fairly decentralized and relies on communication in all directions. Each level gathers information and solves problem. The corporate Environmental Board and Council address issues of corporatewide importance to ensure consistency and appropriate action. We will see later that management processes are in place to eliminate discrepancies

external review of Dow environmental policies. Volvo feels that this approach is too formal and restrictive for its purposes. It wanted a more flexible, adaptive structure, capable of achieving wider outreach.

¹⁵The specific audience-speaker combination varies depending on the topic and the objective. Sometimes the audience is top management; sometimes it is general staff.

¹⁶Leonard-Barton (1996) discusses the issue of corporate values and their operationalization. Corporate values define how employees are expected to act and are operationalized through a myriad of ways. One way in which corporate values are signaled to employees is by the amount of status attributed to, say, a particular technical capability. For example, the elevation of environmental specialists could indicate a high level of importance to company core values. This in turn could serve to attract higher-quality personnel, reinforce their credibility, and promulgate environment as a corporate value. This may be how Volvo management is attempting to elevate environmental concern as a core corporate value. Often, employees confuse a change in operationalization of a value with a change in the core value itself. This is why even small change is often difficult to implement.

across companies if they develop and to verify that corporate environmental policy is followed. The following are the key elements of Volvo's environmental organizational structure:

- A high degree of senior, line management participation.
- Environmental policy boards with decisionmaking authority.
- Parallel organizational structures at corporate, company, and unit levels to aid the flow of information.
- Use of consistent corporate policies and management processes (goal-setting and audits, described later) to drive action. These processes involve some standard-setting and competition between companies and units.

Volvo Car Corporation Environmental Organizations

VCC has a company environmental board to mirror the AB Volvo corporate structure. This board includes nearly a dozen VCC executives from the following line functions: purchasing/production, design, development and engineering, marketing, after-sales, information systems, and the core business areas (models S/V 40, S/V 80, S/V 90, and 940 product series), business strategy, and mobility. This board establishes environmental policies and procedures for VCC and its units. The decisionmaking authority of this board is critical to its effectiveness. Eventually, Volvo will have 18 subordinate boards at the "main units" within the Volvo Car Corporation. Currently, it has boards at six of these units.¹⁷

VCC has decided to place all the environmental experts, 30 to 35 of them, into a centrally managed environmental group called the Environmental Competence Center. The director of the Environmental Competence Center acts as secretary to the VCC environmental board.

¹⁷These groups include the five market areas (VCC-USA, VCC-Europe, VCC-Japan, VCC-Asia Pacific, VCC-International); the three business areas (400 series, 800 series, 900 series); transmission; engine; process and product engineering; purchasing and strategic sourcing; body production/stamping plant; marketing support; quality; strategy and business development; and after-sales.

VCC has about 18 main units. The top manager at each unit is responsible for environmental issues; and these managers are typically not environmental experts. After about six months with the new organization, none of these managers fully understood environmental issues, and only one was problematic. After about 18 months, all the unit managers were aware of and understood the environmental issues. Each main unit was asked by the Director of the Environmental Competence Center to designate an environmental coordinator—someone they could trust. The coordinators are responsible for seeing that audits, plans, and goals are performed and established. This includes developing the units' environmental policy and statement, performing an environmental analysis for the unit, developing the unit environmental program, and establishing an environmental management manual and procedures.¹⁸

It is very important to get someone who is committed and takes the initiative in these roles. Motivation must come from the "heart and the brain" and requires a deep understanding of all the issue elements in the political, economic, and ecological realms. Management should be prepared to modify personnel choices as the system progresses. The environmental coordinators and unit managers from all the units (marketing, plant managers, etc.) meet once a year to discuss issues. Coordinators meet an additional two times per year to share information.

VCC Environmental Competence Center

VCC has a central environmental department, called the Environmental Competence Center, which is responsible for monitoring the political, economic, and environmental aspects of issues.¹⁹ It also

¹⁸There are 40 to 50 people companywide responsible for environmental issues—including the competence center staff and the unit coordinators.

¹⁹In 1997 VCC decided to reorganize the environmental experts and the Environmental Competence Center. Originally it was felt that the environmental staff should be centralized because they were co-developing new skills and analytic tools with the functional experts. Now that the new skills have been developed and these activities have become operationalized, the Environmental Competence Center staff will be dispersed, in small groups (not singly), to such functional areas as production, recycling, and product development. While the Environmental Competence Center will have a smaller staff, the link to strategic planning will become stronger. Finally,

focuses on technical capabilities.²⁰ Environmental experts from the competence center work with the environmental coordinators to develop goals and strategies for the company and the units. The staff of approximately 35 people in the Environmental Competence Center includes experts in all phases of the automobile life cycle: development, production, use, and recycling. The center director believes that having a central “home,” with critical mass for mutual support and information sharing among environmental personnel, is essential. Other Volvo companies have decentralized environmental organizations, where managers and specialists are integrated into line organizations with a small central coordination staff led by an environmental manager.

The Environmental Competence Center is in VCC’s Strategy and Business Development organization. Strategy and Business Development is broadly responsible for property development, product planning, customer software and hardware development, marketing, and target market decisions. Previously, the Environmental Competence Center was part of VCC’s design department and was generally consulted for information on an “as needed” basis. The shift to strategic planning gives the environmental group a broader mandate and an improved ability to address environmental issues proactively. This includes a better ability to think strategically about creating and exploiting an environmental profile for VCC, as well as integrating environmental attributes into facility expansion, supplier relationships, and product support over its lifetime. Volvo personnel feel that product planning, and design in particular, can be a more cost-effective means of managing life-cycle environmental issues. After the product design is determined, it can cost a lot of money to go upstream and downstream for improvements. Linking environmental issues to strategy and business planning brings them closer to the company’s overall strategy, which, in turn, influences the products and their attributes before, rather than after, key decisions are made.

the VCC Environmental Board is now the same entity as the Executive Management (Fräjdin Hellqvist, 1997).

²⁰Its external sources of information include universities, technical journals, and research organizations.

The director of Strategic Planning and Business Development is the line manager for the Environmental Competence Center's administration, personnel, training, and budgeting. Substantive decisions on strategic direction, on the other hand, are made at the top, by the vice president of VCC. For example, if the director of the Environmental Competence Center thinks that VCC's policy should be to eliminate mercury, then this policy will be discussed with the environmental coordinators at their environmental board meeting (or not, depending on the particular issue and timing) and reviewed by the vice president of VCC.²¹ Placing environment in strategic planning is very unusual among corporations, and other Volvo companies have either not organized in this way or have not developed new organizational plans as yet. VCC is a model for others, since by linking environmental to business strategy, the environmental personnel have enough power to accomplish things. In what seems a slight contradiction at first, the Environmental Competence Center does not have a budget to make investments completely on their own (note: they have a budget for training and other staff-related expenses). This way, environment is not seen as an additional cost or a completely separate management process. The competence center is forced to become a part of all business practices and decisions and justify these investments on general strategic and financial grounds.

After approximately one year with the new organization, no one could point to any concrete results of the change, because it was too early.²² The consensus was that the change was good from the point of view of integrating environmental thinking into VCC's broader decisionmaking. Environmental issues were on the agenda "everywhere," and they were getting greater attention in core business decisions within VCC. Importantly, VCC had a process in place to insert environmental considerations proactively and strategically into new products, as well as the clout to do it.²³

²¹Again, according to Leonard-Barton (1996), giving an issue status signals the importance of the issue to the rest of the company.

²²The new organization was established in 1995, one year prior to the time the interviews were performed.

²³This is in contrast to previously, where the environmental staff was not part of the decisionmaking process. They were strictly an information source.

Volvo's general philosophy about organizational structure is to be flexible, ensure that organizations are aligned with the right structure, and employ leaders. If the organization or people are not working out, be open to change. VCC has found that it is more important to have someone with good leadership skills than with substantive knowledge of the environmental area, at least at the manager and coordinator level.²⁴ The director of the Environmental Competence Center emphasized that organizational issues are the most critical aspect of the implementation process and must be addressed early if the process is to succeed.²⁵

To summarize, VCC has an environmental organization that parallels corporate organizations. AB Volvo has environmental boards; one for the entire corporation, one at each company and each main unit within the company to implement the corporate environmental policy. This parallel structure facilitates information flow. Environmental boards and designated coordinators extend responsibility and knowledge beyond the boundaries of environmental expertise. VCC's method of organizing its environmental experts was not imposed on it by corporate management. Indeed, the companies vary in the amount of centralization and decentralization they employ. At first VCC found centralization useful because it provided important cross-fertilization and a sense of purpose to the environmental staff. Environmental Competence Center personnel work with other experts to integrate environmental issues into all other decisions and processes. Moreover, VCC placed the central environmental organization in strategy and business development. This is quite consistent with the corporate environmental policy, which seeks to use environmental issues for strategic advantage. Requiring environmental investments to be made by the other functional units, and not by the Environmental Competence

²⁴Effective managers must have in-depth enough substantive skills to get the job done and a broad enough view to understand the relationship between their actions and the rest of the organization. This orientation is referred to as "T" skills (Leonard-Barton, 1996).

²⁵This echoes Allenby (1994), a pioneer in design-for-environment at what is now Lucent Technologies, who said, "No firm has yet implemented a comprehensive DFE system" and "fully implementing DFE practices will require that most firms develop new competencies, organizations, and information systems as well as changes in organizational cultures."

Center, is also consistent with corporate policy. If environmental investments are to lead to long-run profitability, they must be made on financial and strategic grounds and must not require a separate budget. Moreover, other functional units must embrace these issues for true proactive treatment to be ensured.

THE VOLVO ENVIRONMENTAL MANAGEMENT SYSTEM: CORPORATE KEYS TO PROGRESS

AB Volvo is building an environmental management system to implement the environmental policy. The environmental management system is comprehensive and includes all the management elements outlined in ISO 14000—policy, planning, implementation and operation, checking and corrective action, and management review.²⁶ From our observation, while all these elements are necessary to have a complete environmental management system, at the corporate level two processes—goal-setting and audits—are especially important to drive action at each of the companies.²⁷ Goal-setting generates activities and investments within each of the companies. Audits are important to ensure that companies actually implement corporate environmental policy in a consistent way. They are also an important mechanism for disseminating lessons learned across companies. Although consensus building is important to policy

²⁶In Volvo's view, no one national or international standard offers all that is needed to become world-class. So the Volvo environmental management system (VEMS) is structured to encompass all national and international standards, including ISO 14000, EMAS, BS 7750, and the International Chamber of Commerce's Business Charter for Sustainable Development. Volvo companies and their individual units are free to certify to the most applicable standards. Volvo feels that ISO 14000 is not robust enough because it does not include services (products and processes focus) and is internally focused (no need for third-party audit or public disclosure, such as in EMAS). Volvo wants to do more. EMAS is better on external focus but only applies to production. BS 7750 is somewhere in between. All the standards—ISO 9000, ISO 14001, BS 7750, EMAS—are linked to quality. Volvo will comply with ISO 14020, eco-labeling guidelines, when they are released. Our interpretation of Volvo's position on international environmental management standards is that it employs total quality thinking, where compliance with standards is *not* the ultimate objective. The real objective is self-determination of environmental objectives and investments.

²⁷Remember, AB Volvo is the overall corporate entity or group and the individual companies are Volvo Car Corp., Volvo Truck Corp., Volvo Bus Corp., Volvo Penta Corp., Volvo Construction Equipment Corp., and Volvo Aero Corp.—which are referred to as the companies.

development, competition and visibility (through audits and the environmental board meetings) are used to drive implementation.

Corporate Goal-Setting

The AB Volvo Environmental Board challenges the companies every year to set goals. It is up to the companies to set their specific goals, but the corporate Environmental Board reviews them. Individual company's goals are compared to provide cross-fertilization. Comparison and discussion also help bring up issues that might not have been considered previously by the companies when they set their goals. The Environmental Board will revise the goals if they are either too challenging or not challenging enough. There is spirited competition between the companies (VCC and Volvo Truck are particularly competitive), but this is not driven by expectations of financial rewards. While consensus building is important for policy development, decentralized goal-setting, with corporate oversight, reinforces ownership and stimulates improvement. Decentralized authority is consistent with Volvo's corporate culture. Both Volvo's and the Swedish culture emphasize concern for societal interests. Where corporate culture may not be as strong, such as in the United States, it is unclear whether this approach will be as effective.

In 1993, the AB Volvo Executive Committee implemented the "Environment 95" action program to run to the end of 1995. Twenty goals, ranging from plant emissions to organizational change to specific product environmental performance, were established for the corporation. Each year, progress toward these goals is evaluated and summarized in the environmental report. The specific goals established in 1993, with progress evaluations, are presented at the end of this appendix. In 1996, a new program of objectives, emphasizing the environmental impacts of products, EMS, production processes, and communications, was implemented. This program covers such areas as the VEMS, education, energy use, and water waste.

Corporate Environmental Audits

Environmental audits are performed by the AB Volvo environmental auditor with staff from the various companies. Audits are comprehensive. In addition to organizations within AB Volvo, they review

the systems of major suppliers, waste processing firms, and companies in the process of being acquired. These audits have three purposes:

- Evaluate compliance with existing legislation.
- Assess compliance with likely future legislation.
- Assess implementation of corporate environmental policy. (AB Volvo, 1995.)

Internal audits cover all aspects of the environmental policy and management systems and are crucial facilitators of environmental management. Volvo personnel view them as a mechanism to evaluate progress in a rigorous and consistent way and transfer lessons learned across companies and units. They ensure that corporate standards and environmental policy are met by the companies and force managers to take a hard look in a structured way at what they are doing. Because each company of the Volvo Group can design its own organization to meet corporate standards and policy, in effect each company represents an experiment in environmental management. Audits are used to learn from this series of experiments and to ensure that corporate environmental policy is consistently applied.²⁸ Performance on audits can also be used to generate a healthy competition between business units (Fräjdin Hellqvist, 1996b). VCC has seen that people benefit from the audit experience. Because of its ISO 9000 experience, it is quite comfortable with audits. Although ISO 14000 is different from ISO 9000, the processes are similar. Corporate audits are performed every two to three years. Internal company audits are performed once per year in between. All AB Volvo facilities have been internally audited.²⁹

VEMS at the Company Level

At Volvo Car Corporation (the company level) two processes—goal-setting and tool building and training—are especially relevant to

²⁸Firms that are successful at innovation—both organizational and product—promote experimentation. Most important, they systematically evaluate the experiments, both formally and informally, to share lessons learned (Leonard-Barton, 1996).

²⁹With the exception of recently acquired properties.

incorporating environmental concerns into new product design. Each of these processes and their relationship to environmentally conscious design will be discussed in the next subsections.

VCC sees a synergy between bottom-up oriented and top-down oriented activities required to implement environmental management. Bottom-up activities, such as training, competence development, and communication, improve the understanding of the individual employee. This facilitates a dialogue between all levels of management and expertise. Furthermore, it begins to allow individuals to internalize environmental issues so that their decisions will consider these impacts. The Volvo Dialogue program is its environmental awareness training program, which addresses employee facts and insights. The top-down activities associated with VEMS, such as policy development, goal-setting, integration with business processes, and auditing, generate action. The Volvo environmental management systems (VEMS) is currently under development at one-third of the 18 VCC units.³⁰ New products and process development address improvement. All of these activities will be performed worldwide by VCC. VCC views them as basic elements of implementation, which build on each other. Figure A.2 illustrates the building blocks of Volvo's environmental activities.

How Goal-Setting Is Done at the Company Level

As mentioned earlier, AB Volvo challenges each company annually to set goals for its environmental management system. VCC sets both production and product goals for the following four categories:

- energy (energy efficiency and fuel consumption)
- emissions (manufacturing process and product use)

³⁰These six are the transmission, engine, strategic sourcing/purchasing, stamping production, VCC-UK sales unit, and the Ghent assembly plant; a dealer (not owned by Volvo) is also involved. VCC's aim, which is the objective of the entire AB Volvo Group, is to have a system completely in place by 2000.

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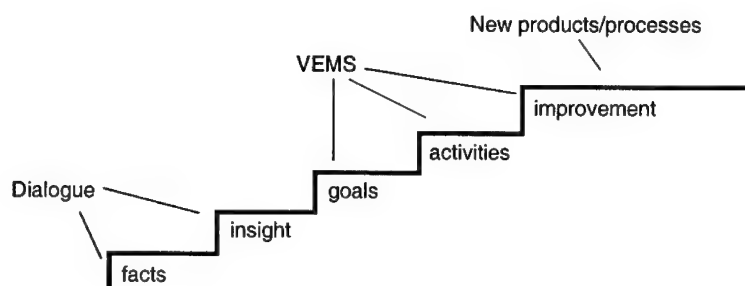


Figure A.2—Building Blocks of an Environmental Program

- recycling and waste management
- sustainability.

All of the goals are reviewed and approved by the VCC Environmental Board, about half of whom also sit on the VCC Executive Board, which is the senior management decisionmaking group for the company generally.³¹ Two features of the goal-setting process appear to be the most critical. First, there must be a framework to guide goal-setting and decisionmaking. Once a goal is selected, it is transformed into a clear target and progress is tracked against that target until it is achieved. Second, the goals are built through intensive networking between the environmental group experts and the other functional units.

VCC's framework for goal-setting uses life-cycle thinking to integrate the set of measures and goals. VCC then focuses on places with the greatest leverage. The environmental goals are a subset of all the general VCC goals, and even the environmental goals are not mutually independent. Because many trade-offs are performed in any decisionmaking process, a structure or framework helps make these

³¹Since the interviews were performed, VCC has reorganized its environmental management organization—now all members of the VCC Executive Board are on the Environmental Board (Fräjdin Hellqvist, 1997).

trade-offs easier to assess.³² The Director of the Environmental Competence Center stressed the importance of having a framework to integrate the goals. In the past, VCC did not have a framework, so regulations drove structure. Having a framework aligns investments with company strategy and provides a means to prioritize those contributing the most to strategically desired environmental improvements. Moreover, it focuses management attention on the important issues and facilitates action in a technical environment, which is highly quantitative. Finally, the structured goals and targets help to relate specific activities to company goals.³³ Clear priorities are used for decisionmaking and investments.

VCC's priority for investments is clear: first business, then safety, and then environment. Specific investments are always chosen by senior management, so environmental issues are not treated differently. VCC invests in the economically feasible technology with the best environmental performance attributes. This may mean that VCC invests in the "80 percent solution" until it becomes clear that the "100 percent solution" is the effective way to go. However, there is a minimum acceptable environmental performance—no new investment can degrade existing environmental performance. Corporate guidelines for investments include a "checklist" that ensures that each department, including the environmental department, is involved in the decisionmaking process for each investment. Incremental environmental improvement is VCC's general strategy. Where warranted, significant investments will be made to improve

³²Walley and Whitehead (1994) point out that one of the real problems with Porter's win-win paradigm is that searching for these opportunities can divert too much management attention from other core business processes. An example of a win-win situation found in a structured way was at the Torslanda plant. The plant performed a waste management study over a two-week period and found a way to save \$3 to \$4 per part through packaging reduction without any investment. This structure is provided by the combination of organizational entities, the life-cycle framework, goals, and priorities.

³³The use of long-term strategic planning to guide investments, which meet financial criteria, is recommended by Claude Fussler, Environmental Health and Safety, New Businesses, and Public Affairs, Dow Europe. It is the long-term view that allows innovative companies to persist, to better anticipate major technological changes, and to exploit this change for their competitive advantage. Given the three drivers of environmental issues—population and demographics, environmental stress, and value creation—he anticipates significant innovations in the future (Fussler with James, 1996, pp. 20–21).

environmental performance. Like any other strategic investment, environmental investments are justified in terms of competitive advantage.

Second, the goals are built through intensive networking between the environmental group experts and the other functional units. Goals tend to be driven top-down within VCC, with a heavy reliance on information collected through the networks of environmental coordinators from the business units and environmental experts from the Environmental Competence Center. That is, VCC tests goals through the network, but will announce them before clear implementation plans are in hand. VCC then develops an implementation plan using the expertise from the units.³⁴ Especially critical are the ways in which others are enabled to make informed decisions regarding environmental issues, because many individual decisions will determine the ultimate environmental profile of a product. Whichever environmental actions are undertaken, however, the investments must compete on an equal basis with any other investment.³⁵

The environmental experts motivate line organizations to consider environmental effects and provide expertise on environmental issues. The line experts are responsible for actually incorporating environmental concerns into their analyses and decisions. The networking is performed in all settings—design, advanced engineering, production, etc.—and is reinforced with the environmental boards and working group organizations.

The business units have the required expertise to provide feedback on the feasibility of the goals and to offer suggestions for ways to meet the goals. So the environmental experts work with the line or other functional experts to develop feasible targets, given environmental as well as business development objectives, and to overcome

³⁴This sounds like the Toyota concept of target pricing—set an acceptable price and then work backward to get cost down enough so that you can charge that price.

³⁵Texas Instruments has a similar sounding process that it calls “catchball.” In this process, the business units identify goals and share them with other units, as well as with upper unit management. This helps build consensus around a goal and creates buy-in to eliminate the barriers that may hinder achievement of the goal (Ufford, 1996).

barriers to these objectives.³⁶ By working with relevant functional experts, Environmental Competence Center personnel create buy-in and generate more creativity than if they worked in isolation. For example, a design engineer, not an environmental expert, suggested extending the tailpipe life to meet an environmental goal. However, because this idea did not pass muster with the business side of the house, it was eliminated as an option.

Competence center personnel may also help the other functional experts relate their actions to specific measures and goals. The company's environmental training provides a common basis of understanding for dialogue within and between all levels. The Environmental Competence Center measures success by the number of debates and dialogues on environmental issues that arise. When the VEMS is mature, environmental improvements will be completely integrated with line management.

The Environmental Competence Center creates visibility for these goals and builds political support for their realization throughout the company. The center works to build an organizational process and the required competencies to implement and internalize these goals.

How Goal-Setting Relates to Product Design and Advanced Research

As mentioned earlier, VCC focuses on four basic sets of environmental goals, and it either has, or will have, explicit targets to move toward. The goal set is presented in Table A.1. The development of these goals requires coordination between the Environmental Competence Center and the units that will have to implement them—in this case product design and advanced research.

VCC has clearly prioritized its product-oriented issues in this order: energy, emissions, and recycling. These priorities have evolved over 24 years and are not mutually exclusive. Progress toward these goals can be difficult, requiring lots of analysis and judgment. Or progress

³⁶This is feasible in part because there is greater knowledge of business issues at the lower levels of the corporation than even five years ago. Then, the bigger picture was only in the heads of top management.

Table A.1
Volvo Car Corporation Goal Set

Goal	Production, Services	Products
Energy use/fuel consumption (CO ₂)	Specific numerical targets pending	Cut 25% by 2005 (1990 baseline)
Emissions (VOCs, etc.)	Explicit time schedules by chemical (including CO, HC, NO _x , PM, ...)	Explicit time schedules by chemical (including CO, HC, NO _x , PM, ...)
Recycling/waste management	Still pending announcement	85% recycle by 2002 95% recycle by 2015 ^a
Sustainability	"Use life-cycle assessment" ^b	"Use life-cycle assessment"

^aActually, Swedish law requires the more stringent of the total disposed weight requirements and the recycling percentage to apply. Specifically, by 2002 either 85 percent of the car by weight has to be recyclable or not more than 152 kilograms can be sent to disposal, whichever is more stringent. By 2015 either 95 percent by weight must be recyclable or no more than 50 kilograms can be sent to disposal.

^bWhile, life-cycle thinking is not new to Volvo, the broad discussion suggests that it can be conducted much more thoroughly to understand more long-term implications of decisions made today. Thinking in terms of sustainability is quite different from thinking in terms of LCA analysis to support traditional financial decisions.

can be straightforward and simply a matter of awareness and concern. For example, energy issues are tricky because improved fuel consumption requires new technologies and is a systemic issue touching on many elements of automobile design from weight to shape to engine design to use to the fuel itself. Therefore, designers look for leverage points. Global warming is driving this interest. Emissions issues are more straightforward. Process designers know what needs to be done and employ everything from improved house-keeping to process change. Some multimedia issues arise as well. Emissions during manufacture and during vehicle use present challenges, but it is relatively easy to relate design changes directly to the particular emissions to reduce. Recycling is fairly straightforward and is in the company's self-interest because of the regulatory fines. Material used in manufacturing a car is either captured and reused or burned to recover some energy value. So recycling is just a matter of doing it.

Goal-Setting in Advanced Engineering

The integration of environmental issues into business processes is manifested in R&D planning through advanced engineering. Advanced engineering activities are performed before product design, that is, before there is a letter of intent. Advanced engineering is seen as a low-risk mechanism, relative to platform-related investments, to test solutions to technical problems. The technical gaps on the business development side can be addressed in the advanced engineering context at minimal cost relative to platform development.³⁷

The Environmental Competence Center works with each department—exterior, body, chassis, engine, transmission, styling, interior, etc.—to develop an environmental investment strategy for its research investments. The Environmental Competence Center is responsible for monitoring the political, economic, and environmental aspects of issues as well as technical capabilities. Its external sources include universities, technical journals, and research organizations. These trends are then combined with business development needs to contribute to the R&D agenda so that technical capability is ready for product lines as needed. The center's information gathering and internally oriented outreach activities also help train functional line managers or make them aware of new technological solutions.

Working-level personnel have developed a structured process to discuss environmental issues using the template shown in Figure A.3. First, they walk through the aspects relevant to the product—resource use, clean production, emissions during use, materials use, noise, recyclability—and determine what a “green” system might look like. They determine the relationships between system characteristics and these environmental characteristics. Once the baseline characteristics are established, they identify the technological barriers to improvement. Technology investments to

³⁷Experimentation and prototyping are low-cost ways of testing new ideas and hedging against catastrophic failure. To experiment successfully, a company must recognize that failure is part of the learning process. These activities are generally performed well by knowledge-building companies (Leonard-Barton, 1996).

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DEPARTMENT XX				
Aspects	Green characteristics	Areas for improvement	Activities	Time frame for introduction 96, 97, ... 2006
Efficient use of resources				
Clean production				
Emissions during use (CO ₂ , fuel consumption, NO _x , VOC, electrical)				
Clean materials use				
Allergic/toxic reactions				
External noise				
Recycled vehicle				

Figure A.3—Template for Advanced Engineering Planning

eliminate these barriers are planned over a 10-year horizon. The actual investments are made based on market demands and anticipated market introduction by competitors. So the matrix presented in Figure A.3 is fleshed out for each department—exterior, body, chassis, engine, transmission, styling, interior, etc.

Finally, a life-cycle assessment using EPS is performed to determine high-leverage areas and prioritize investments. Thus, investments are ultimately prioritized according to market interest (willingness to pay), competitor actions, and leverage over environmental performance.

To summarize, the line organization—advanced engineering in this case—is ultimately responsible for making the investment decisions. The environmental group provides recommendations, and the proj-

ect personnel and advanced engineering personnel work back and forth on what is required and available. To back up the working-level personnel, the director of the Environmental Competence Center discusses the plans and progress with the top manager of each department twice per year. VCC has completed this analysis for 10 departments and the complete vehicle over an 18-month period. The director of the Environmental Competence Center has met with each department manager twice.

This structured approach with the template and investment strategies helps departments combine strategies for all performance attributes and facilitates more cost-effective decisions. Some departments have been more open to this approach than others. In general, the departments tightly coupled with customer demands, such as transmissions, engines, and interior, are more responsive to this process than other departments have been so far.

Environmental Management in Product Development

Volvo design processes. Volvo design teams are cross-functional teams that stay in place for the duration of a project, defined as ending three months after product launch/production start.³⁸ At peak, a project will have 100 engineers working on the design team. Design teams have been restructured so the manager has more incentives to build staff skills, while the product is the responsibility of the entire team. This is somewhat new at Volvo, and Volvo feels that it allows for a greater degree of creative input to design because the whole team gets recognition. This approach also gives more decision-making authority to the individual team member. User or customer preferences are fed through both the dealerships and marketing organization. The dealerships send information on repair records, warranties, servicing, etc., to designers through the quality system. Marketing seeks input through focus groups, research studies, and surveys. Common environmental awareness training, the Volvo Dialogue, facilitates the incorporation of user or customer input.

³⁸Design time periods are two to three years if working from an existing platform and engine, six to eight years if a new platform is being developed, and five to ten years if a new engine is being developed.

In the first phase of design, the new property requirements are established and documented in a "letter of intent" for a new automobile. These simply include a basic description of the target market and price goal for the automobile. Property requirements are then described in general terms in the areas of performance, safety, and environment, and additional analysis is performed on the target market and willingness to pay. The third phase of design, the property analysis phase, is iterative. Initially the property description is developed in nonquantitative terms. A functional analysis is performed from the complete automobile to lower and lower systems, components, and finally parts, to determine overall characteristics. The functional analyses are iterated at all levels to refine the technical and functional requirements of the automobile and its systems. The result is a complete quantitative description of the automobile as well as its detailed components and parts.

The environmental issues are part of roughly 35 overall attributes of concern for an automobile.³⁹ For example, attributes include automobile weight, air resistance, and rolling resistance. The only attributes exclusively driven by environmental requirements are emissions and recycling rates, followed closely by materials and fuel consumption. But environmental requirements affect virtually all 35 attributes in some fashion. Ultimately the project manager must decide whether or not to meet the environmental goals. If they are not going to be met, marketing might be consulted. Many attribute trade-offs are made, and on occasion, if the goals cannot be met, the project review board can cancel the project. Cancellation has occurred, but it is a big deal. In the past, environmental issues have not been weighted as heavily as they are now. Environmental attributes are justified on the grounds of market demands today and those expected in the future.

Incorporating environmental concerns. The Environmental Competence Center facilitates design-for-environment in a number of ways. At the management level, it reviews strategic issues with each of the design departments for a particular product. At the working level, the competence center staff engage design teams directly to

³⁹Design is a high-leverage phase and is cost-effective because there is considerable freedom during this phase. However, the problem becomes one of establishing priorities and decision criteria for making the associated performance trade-offs.

develop and monitor environmental performance attributes. At the skill level, the center co-develops tools and educates engineers on the environmental effects of their designs.

At the management level, the director of the Environmental Competence Center has had a series of discussions with the managers of each of the design organizations, such as design and styling, to cover the environmental issues in their area. She has done this with all groups, about 20 in total, over the last year and a half and is ready for the second round. Through these conversations, the director of the Environmental Competence Center has increased the awareness and demonstrated the importance of these issues. After these sessions, some groups have returned with interesting ideas on how to approach the environmental issues. This is taken as a sign of progress.

At the working level, each system (e.g., transmission, gears, door panel, instrument panel) has four or five engineers working on the design. The Environmental Competence Center contributes one individual to each cross-functional team. The center personnel work with the system engineers to establish targets for environmental attributes and develop awareness. The center also monitors and tracks the environmental attributes of concern (e.g., recycling rate, fuel economy, emissions, materials, weight, noise) to ensure that they meet the targets established. Center personnel also suggest improvements and check for internal consistency. They plot actual performance against each goal for the environmental attributes of concern. If an issue or trade-off cannot be resolved at the team level, it is elevated through line management and may involve other line functions, such as marketing. This option is not exercised often. Ultimately, design projects are monitored by a project review board, which has final say in the outcome of the series of design trade-offs.

Individual design engineers are introduced to environmental thinking in two ways: through recycling analyses and life-cycle environmental assessment analyses. Both approaches seek to improve thought processes used by designers to consider the long-term impacts of design decisions. Volvo personnel believe that thinking recycling all the way through requires design engineers to consider long-term impacts of material selection. How will material choice affect the ability to reuse or recycle the component or part? How will

material characteristics hold up after recycling? How many cycles can the material withstand? Recycling is also fairly straightforward to motivate because of the Swedish law requiring recycling rates of 85 percent by 2002 and 95 percent by 2015. If Volvo does not meet the provisions of the law, it either must raise car prices or earn lower profits. The Volvo joint venture dismantling facility also provides practical experience with dismantling and recycling so designers can view practices and results first-hand.⁴⁰ Recycling issues are more straightforward and somewhat easier to understand than all of the environmental life-cycle effects.

Life-cycle assessment issues are broader and longer-term than recycling. The life-cycle assessment model and database used by Volvo is called the Environmental Priorities Strategies (EPS), described in greater detail below. It calculates all environmental effects from biodiversity loss to human mortality for material and process choices. The time horizons are long-term. By using the EPS system, designers improve their understanding of the relationships between design features and material choices and the environmental impacts. This increases their appreciation of the environmental ramifications of numerous design trade-offs. Today, not every design engineer is trained to use EPS. Nor has it been used on an entire car design. While EPS analyses are comprehensive, short-term profitability ultimately limits the number and type of issues that can be addressed by Volvo, so it is necessary to have a framework of metrics and goals to target and prioritize analyses.

We did not discuss how much attention the project review board gives to environmental issues. Generally it appears that decisions on environmental issues employ a bottom-up process, where working-level environmental personnel build awareness and work with designers to establish priorities. Design decisions are made at the lowest appropriate level by the functional experts. The awareness of

⁴⁰The joint venture among VCC, Stena Bilfragmentering AB, AB Gotthard Nilsson, and Jönköpings Bildemontering AB is called Environmental Car Recycling in Scandinavia (ECRIS). It was established in 1994 to scrap vehicles and process waste materials from suppliers, dealers, and production operations. The test facility is also used to generate parameters for the life-cycle model EPS (specifically the trade-offs between initial raw material use and energy consumption of recycled materials) and, as mentioned, to train design engineers. Material recycling and energy recovery techniques and recycled materials markets are evaluated for profitable dismantling.

environmental issues generated at the management level reinforces this bottom-up approach during project review. Corporation goals and market analyses are the only real "forcing functions" from above.⁴¹ Design processes and environmental attributes are linked to financial systems. These financial systems approach activity-based structures but are not identical with them. Activity-oriented analyses are performed frequently on a project basis and have led to unanticipated results.

To summarize, VCC has approached product design from many dimensions. Goal-setting is an important part of implementation. Structured goals provide strategic focus. They help to relate specific activities to company goals and facilitate improvement. Clear priorities in this case—business, quality, safety, and environment—make decisions easier. Market interest and company strategy motivate individuals to try to meet and improve goals. The Environmental Competence Center personnel actively inform and remind others of these motivations. Because of this, and the general Volvo corporate culture, most management processes rely on cooperation and competence development. Environmental Competence Center personnel interact with design organizations at two levels. At the manager level, the director of the Environmental Competence Center builds political support and visibility for environmental goals. At the working level, individual relationships increase awareness and support for the goals. These relationships between Environmental Competence Center personnel and design personnel are also instrumental in helping designers develop new competencies. Individual designers are better equipped to think about long-term effects of their decisions by working through recycling issues and environmental life-cycle assessments. Individual competence is especially important because new product design is characterized by decentralized decisionmaking and many design trade-offs.

⁴¹Xerox has a different corporate culture and procedures. Xerox managers feel that its specific environmental design exit criteria are key contributors to its design-for-environment program. These criteria make design engineers pay close attention to environmental attributes. Note, other key elements of the Xerox program include training and use of a blended unit cost, which includes production and disposal expenses to encourage ownership (Azar, 1996).

Environmental Management Tools and Training Programs

The second major aspect of environmental management implementation that is especially important to implementing design-for-environment is the development of analytic tools and specialized competencies. Training addresses both individual values and awareness, while analytic tools facilitate environmental analyses and codify values for the analysis process. Three of the major tools and training programs are described in this section. These are EPS, a life-cycle analysis tool; MOTIV, a chemical database; and Volvo Dialogue, a general environmental training program.

Life-cycle assessment: Environmental Priorities Strategies (EPS). EPS is a life-cycle assessment tool used by design engineers at VCC. EPS has two elements, a database and a methodology, that employ sustainability principles to calculate the environmental effects of products.⁴² Volvo is one of about a dozen industrial firms in Sweden that have collaborated with research organizations to develop EPS. This subsection will briefly review the guiding principles used to develop EPS to provide a foundation for understanding how it has actually been used by designers at Volvo. Volvo finds the structure of the system useful for thinking through all the environmental issues associated with product design—for educating product designers as well as for determining high-leverage areas for investment and additional study. As discussed in this subsection, it does not however,

⁴²The most important aspect to implementing new technical processes and tools is to treat and manage the implementation process as a innovation itself, rather than as “the mere execution of a plan.” Using the analogy of new product development for the implementation of new processes and tools means that the customers are the internal organizations that will employ the new practices. It follows that successful implementation will involve users to develop the new process or tool design and create buy-in. As much attention should be given to selecting experimental users as is given to the specific tool or process design. In particular, experimental users should be interested and willing. They should also possess a knowledge base representative of the user group. Co-development is a very useful way of incorporating user input because both users and developers are forced to share problem-solving and hence responsibility for the success of implementation. Furthermore, mutual understanding is garnered at the group level rather than the individual level. Moreover, mutual adaptation, where the new tool is influenced by the users at the same time that user processes are affected by the tool, is more often associated with co-development. This iterative process of introducing new concepts with the requisite organizational change is more easily addressed with co-development. This can also help mitigate the negative affects from uncontrolled change. (Leonard-Barton, 1996.)

use the system in a fashion completely consistent with the objectives of the developers. For a more detailed history and description of EPS, see Chapter Two.

What is EPS? EPS is an analytic tool that performs the four major steps in a full life-cycle analysis. These steps are:

- Establish goals and *scoping* components that explicitly identify the reasons for performing the LCA.
- *Inventory*, or characterize, the life-cycle environmental impacts of a given product to include natural resource use; energy use; and air, water, and soil emissions during manufacture and use.
- Assess the *impact* of the products' emissions and resource use on human health and the environment, such as biodiversity loss and air quality.
- Evaluate *improvement* opportunities and options through alternative product designs.⁴³

Industry participants and research scientists agreed on several ground rules or guiding principles for EPS. These guiding principles were established to ensure that EPS would be useful to and employable by design engineers while meeting the tenets of sustainability and considering all environmental effects appropriately.⁴⁴ The following are the agreed-on principles:

⁴³Life-cycle assessments are separated into component parts by ISO, SETAC, and others involved in guideline and methodology development. These components are called inventory assessments, impact assessments, and improvement assessments. ISO is developing guidelines, with mixed degrees of success, for each of these components (proposed standards in the 14040 series) (SETAC, 1990, p. xviii; Ryding et al., pp. 3–4).

⁴⁴Allenby (1996) placed the three extant life-cycle assessment methods into the following categories: high-level qualitative matrixes (AT&T/Lucent Technologies' approach), which are primarily good for internal use, involve lots of judgment, and are not good to communicate to external audiences; quantitative methods with detail on values (EPS), which cause problems when costs or values are unknown; and the thorough and detailed approach (SETAC), which can get overly complex and detailed given data availability and large uncertainties.

- Create a tool that is quick to use and can be incorporated into multidimensional product design analyses. Generate one quantitative measure for all environmental impacts.
- Use a comprehensive perspective; that is, include all environmental effects.
- Treat all generations and geographic areas of the world equally.
- Employ the precautionary principle to environmental threats.
- Provide a uniform baseline as a default scenario.
- Maintain transparency and expose all assumptions clearly.
- Include uncertainty explicitly.
- Weight safeguard subjects with willingness-to-pay information to get one numerical result.

The EPS uses average-risk-assessment methodologies to relate risk to results, such as human mortality or loss of biodiversity, in five safeguard subjects: biodiversity, human health, production, resources, and aesthetic values. Because EPS employs sustainability principles, results are based on assumptions with very long time horizons (hundreds of years in some cases) and broad societal values.⁴⁵ Volvo finds EPS useful to design-for-environment implementation in several ways. And while the principles listed above are important to the EPS rationale, in a practical sense, Volvo views the outputs in numerous ways.

EPS helps with environmental strategy formulation and designer awareness. One of the ways in which Volvo finds EPS useful is for developing an overall environmental strategy. Since the environmental issues associated with the automobile life cycle are complex and wide-reaching, it is very useful to have a method for structuring and assessing the myriad sets of issues. The structure of the EPS system and the framework of the resulting analyses help the company organize environmental goals, look for high-leverage areas, and

⁴⁵One ground rule established between industry and scientists was that EPS be comprehensive, because in early stages of design there is considerable freedom, and the opportunity to affect environmental performance is great. This leads to assumptions about sustainability. See Chapter Two for a longer discussion of this rationale.

communicate information to managers, designers, and customers alike. The managers and designers can then focus their analyses and investments on those areas that provide the greatest leverage to environmental issues and may constrain automobile design in the future. An example of how EPS helped Volvo focus on an issue previously given limited attention concerns radium, a rare-earth metal used in electric car batteries. The natural resource calculations in EPS indicated depletion of this resource. With this focus in mind, designers and environmental experts reviewed discussions in the scientific community about this issue, which they might not have noticed otherwise. Also, EPS analyses provide a foundation and rationale for communicating environmental impacts of automobile design both within the corporation (to business managers and decisionmakers) and outside (to policymakers, customers, and the public).

The other primary way in which EPS is used by Volvo to implement design-for-environment is to educate designers about environmental issues. The entire set of environmental issues and the relationship of design to environmental impact in EPS are used to train designers to think about the long-term and the life-cycle environmental effects of their design, material, and process choices. For example, EPS helps designers walk through the material selection process to understand the effects of their choices on recycling potential and multi-life products. Currently 20 to 30 design specialists at Volvo are being trained on EPS. They are learning the tool and the thought processes. Environmental experts see that this additional understanding motivates designers to consider and take environmental issues seriously. It also provides them with the capability to do so.

The application of EPS is limited. The EPS model and database are still under development. Even so, Volvo analysts are comfortable that results are now accurate enough for decisionmaking, if a specialist operates the model and interprets the results in the context of business decisions.

Generally EPS is applied strategically, that is, on those systems where processes or materials can be changed or where there is potential for significant environmental improvement or when analysts want to compare two or more concepts in the early design phases. Right now, the decisions on where and how to apply EPS are made with the help of the environmental experts. Only on a limited basis has EPS

been used for entire systems: Volvo's environmental concept truck, environmental concept car, and environmental concept bus. For example, EPS has been used on design of a bumper because the results are easier to comprehend and apply, making it a good application for educating designers on environmental issues. They can use the model and its structure to generate the right questions about design choices and environmental impacts, such as material use and recyclability, and thus to build design competencies on environmental effects.

Volvo also breaks down the results of EPS into their constituent parts for product design analysis, instead of always using only the aggregated numerical output. The ability of the company to develop sustainable products in the EPS sense is limited by its planning horizons and financial constraints. Therefore, Volvo will substitute five- to ten-year projections for resource prices (versus recovery costs as provided in EPS) and will focus on the emissions piece. For the automobile, such emissions as CO₂, CO, and NO_x as well as prices of the rare-earth metals dominate Volvo's concerns. Not surprisingly, these modifications are not recommended by the EPS developers because they violate the established principles.

Finally, because of the way EPS was developed, there are many potential benefits beyond product development. First, EPS is really a database and a model. The database especially requires constant updates and refinements. Because EPS is a collaborative effort, these expenditures can be shared with other industrial companies. In addition, because EPS was developed by major companies in Sweden, in collaboration with a research institute and the government, the baseline data and scenarios can easily be used for discussions on specific environmental issues among all stakeholder groups. In fact, model results have been used successfully to recommend changes to specific elements of the Swedish recycling law to increase allowances for energy recovery.

To summarize, the comprehensive treatment of environmental issues and the structure and framework developed for the system help Volvo link the various environmental goals and targets that it has established and to communicate priorities and decisions to others both internally and externally. In addition, EPS is a design aid that walks designers through the environmental effects of their deci-

sions and, because of this, builds new competencies to handle environmental issues. In addition to EPS, Volvo also has design checklists and guidelines, training, and manuals to aid design decisions.

The Volvo chemical blacklist. The blacklist is a group of chemicals prohibited by Volvo for its own operations as well as for those of its suppliers. The list is a compilation of substances banned in countries around the world, as well as those that Volvo has deemed too risky to use. The associated "gray list" includes those chemicals that Volvo is phasing out. These lists are updated approximately once per year. They are fairly new (about one year old) and change often, so they have not been electronically linked to the corporate chemical database, MOTIV, as yet. This list is available to all Volvo employees, including design engineers—not only EH&S specialists—so all employees can easily avoid using these chemicals in the first place.

Chemical database: MOTIV. MOTIV is a corporate database of 4,000 chemical products used by AB Volvo (10,000 different chemicals are in use worldwide). It was established in 1991 and includes information on chemicals used in all products and processes in all Volvo companies. It was developed to help minimize the use of environmentally hazardous substances and to simplify the specification of various chemicals. As a result of having this information generally available, the number of chemical products purchased by Volvo per year was halved from 800 to 400 (AB Volvo, 1994b) and the use of several substances was discontinued (AB Volvo, 1995). MOTIV cost approximately \$380,000 to develop and costs \$170,000 per year to maintain. As of spring 1992, Volvo had already saved \$170,000 in one year, after expenses (Rothenberg and Maxwell, 1993).

The database is managed by the safety engineers and includes information on environmental effects, health, fire, transport, place of use, and chemical composition. Chemical products are submitted by the users and reviewed by Volvo's occupational health and safety organization with input from the environmental organization. The chemical recipe for each chemical must be submitted by its supplier to Volvo or the product is not purchased. This sensitive information is accessible only to a handful of users at each company.

This database can easily be consulted to ensure that chemicals on the blacklist are not being used or to determine the locations of par-

ticular chemicals in use. Designers can use it to focus on those already in use and to see which chemicals are being phased out by the corporation. Because this information is readily accessible, it can be used both to resolve short-term emergencies and to assist in product and process chemical choices. "Environmental questions have to be answered directly in product development. These are the best people to make the decisions." (Rothenberg and Maxwell, 1993.)

Environmental awareness training: Volvo Dialogue. The Volvo Dialogue program is an environmental awareness program that is provided to all VCC employees worldwide, dealers (both sales and service personnel), and suppliers. The program has been modified slightly for U.S. personnel. The Dialogue program is geared toward changing employee attitudes and values regarding the environment by giving employees information to do so.⁴⁶ Volvo has never had a training program so large. When the program is complete, after three years, more than 70,000 personnel involved in every product stage, including all Volvo employees, as well as dealers, sales and service personnel, and suppliers, will have been trained. Attendance has not been a big problem, although there has been some slippage in scheduling the latter sessions.⁴⁷

In order to change behavior, VCC's environmental experts believe that they must modify the attitudes and values of employees who are either open to change or recognize that there is a problem.⁴⁸

⁴⁶Safety is the highest corporate core value and has been part of training since the company's inception in 1927. To get awareness of the environment to the same level will be more of a challenge. Because safety is a more immediate life-and-death issue, its importance is easier to explain than that of the environment, where the issues can be longer-term and indirect.

⁴⁷Only one other company that the authors are aware of has undertaken such a large training program—Motorola. Motorola planned to train more than 100,000 employees in one eight-hour environmental awareness session from 1993 to 1996 (Eagan, Koning, and Hoffman, 1994).

⁴⁸This approach contrasts with the approach taken by the Department of Defense on racial integration in the late 1940s and early 1950s. Largely considered a success relative to private attempts at integration, DoD implemented racial integration by espousing a clear policy with swift enforcement. The key element of this program was that it sought behavioral, not attitudinal change. Shared work-tasks facilitated this change. Note, at the time this policy was being implemented, there was strong public opinion against racial integration (Rostker et al., 1993, pp. 183–190). It is not clear how analogous this situation is to environmental issues. In contrast to general attitudes on integration in the 1940s and 1950s, public opinion is generally supportive of envi-

According to many, "Education can be a powerful potential change agent for companies," and can provide a common vocabulary for all participants (Eagan, Koning, and Hoffman, 1994).

The Dialogue program's three sessions address the "facts" and "insights" steps in the staircase presented in Figure A.2. The first session is meant to scare and shock or get attendees' attention. This is presented by a professional trainer in a venue for about 250 people. The second session is a dialogue between a Volvo employee and other staff to relate transportation issues to environmental issues. The third session addresses Volvo and the environment. It considers historical aspects but concentrates on relating individual contributions to corporate goals. The second and third sessions are in smaller groups of 15 in interactive sessions, or "dialogues." A colorful three-ring binder of materials is provided to personnel.⁴⁹ Time between phases is considered a key aspect of the program. This time allows employees to digest messages and provides for more interactive sessions in the latter phases.

Employees' attitudes are surveyed to determine the effect of training and awareness programs. In 1994, Volvo surveyed employees to assess their attitude toward environmental issues. In that survey, on a scale from one to five in terms of awareness and willingness to change behavior (1 = Unaware, 2 = Questions the problem, 3 = Realizes there is a problem, 4 = Willingness to change, 5 = Actively changing), Volvo employees were between 2 and 3. In a 1996 survey, employees were between 3 and 4. These results, along with the increase in the number of environmental questions coming from employees to the environmental staff, is interpreted as progress.

Design engineers question the utility of this training program for their purposes because they feel they already know the material. However, the common training allows the engineers, and anyone for that matter, to have a level of understanding common to personnel

ronmental causes. Moreover, behavioral change is difficult to prescribe or enforce. This is particularly true in the case of pollution prevention, where success depends on the creativity of individual employee ideas and actions.

⁴⁹For comparison, the Motorola awareness program is presented in one eight-hour session, which covers environmental problems and problem-solving ideas, global environmental issues and their relationship to the individual, environmental regulations, and the value in going beyond compliance.

corporatewide. Therefore, engineers can more effectively respond to input and questions by others.

The other Volvo companies—bus, truck, aero, and construction—are beginning the Dialogue program developed by VCC. Over the years, other training courses for specialized issues and audiences have been offered within various companies in AB Volvo.⁵⁰

To summarize, the second major aspect of environmental management implementation is the development of analytic tools and specialized competencies. Environmental awareness training addresses both individual values and awareness. Analytic tools facilitate environmental analyses and codify values for the analysis process. These are particularly important to design-for-environment implementation because ultimately the environmental profile of a product is determined by many cumulative decisions made by design engineers and others, not the environmental experts. EPS, a life-cycle analysis tool, is used to build new competencies among design engineers. The life-cycle view and the EPS analysis framework also link the various goals and targets that VCC has established. The MOTIV chemical database makes information available to the design engineer and not just EH&S specialists. This has helped reduce the number of chemicals used at AB Volvo. Volvo Dialogue, a general environmental training program, increases the understanding and appreciation of every Volvo employee. In order to implement the environmental policy, all employee behavior, attitudes, and values must be modified. VCC seeks change through education. Finally, education provides a common vocabulary for all employees.

Suppliers. Volvo requires its approximately 500 suppliers to know Volvo's environmental policy and to establish and maintain an environmental management system of their own that is "in the spirit" of Volvo's. The director of the Environmental Competence Center said that no time frame was put on the suppliers, but a Volvo brochure released in summer of 1996 implies a time frame. If suppliers fail to establish an EMS in the spirit of Volvo's, they will be dropped.

⁵⁰VCC had published a brochure three or four times per year, titled "Clear Facts," to generate information on environmental issues. This publication has been discontinued.

According to the director of the Environmental Competence Center, the suppliers were openly astonished that Volvo was being so tough.

Some suppliers, now that they are aware of Volvo's specifications and priorities, are improving Volvo's specifications and making Volvo aware of the environmental effects of these specifications. So information is flowing in two directions. This is similar to the outcome of employee training as well and is considered a sign of progress.

THE ENVIRONMENTAL PRIORITIES STRATEGIES LIFE-CYCLE ASSESSMENT

Life-cycle analyses, whether quantitative or qualitative, are an integral part of any design-for-environment program. These analyses, however, often prove difficult, particularly in the case of complex products that require systems integration. EPS in particular is important to Volvo's program in that the methodology gives design engineers a framework to assess the environmental impacts of their design decisions and material choices. In this way, it builds new competencies and aids analysis. Significantly, EPS also helps environmental managers and design engineers select strategic areas to focus additional analyses and to make investments. Because life-cycle analyses are so important to design-for-environment and EPS is important to the Volvo program, this section provides additional information on how EPS was developed and the underlying methodology.

In the early 1980s, members of the Federation of Swedish Industries began to cooperate on environmental issues.⁵¹ This led to the development of five environmental handbooks and common tools:

- A handbook for managing environmental compliance.
- Special issue pieces, such as one on global warming.
- An environmental auditing guide.

⁵¹At this time, environmental issues were getting more attention and the member companies were not well positioned to deal with them. So the federation began to cooperate on these issues in addition to previous interests and extend their cooperation on lobbying efforts to other issues (Almgren, 1996).

- A report on product stewardship principles (English version will be published soon).
- EPS development.

EPS is a life-cycle analysis tool. It has a database on environmental impacts (energy, emissions, waste generation) for various materials and industrial processes and software models for product and process design. Results called environmental load indices are calculated for various materials and processes. These load indices can be measured in units per kilogram, square meter, or piece (environmental load units, ELUs) and are based on the environmental effect in five general categories: biodiversity, human health, production, resources, and aesthetic values.

Origins and Approach

EPS has been developed through the cooperation of industry members, a trade association, and university researchers. Working groups are staffed by individuals from Chalmers Technical Institute, IVL (the Swedish environmental research institute), the Federation of Swedish Industries (a lobbying organization), and Volvo. The EPS system, including the database and model, will now be managed by the Life-Cycle Institute, housed at the Chalmers Technical Institute, also referred to as a Competence Center, which has just been established.⁵² Future development will focus on the database because the methodology has been fairly well established. On average, 12 Swedish companies are involved at any point.

Development of the system began in 1991, but initial discussions date to 1989–1990. At the original meeting, several companies decided to develop the EPS system together to aid decisionmaking on environmental issues in new product design. These companies had begun to realize that the focus of environmentalists had shifted from production emissions to products. If products were required to be more environmentally sound, companies would have to possess the analytic tools to address these issues, but the companies had no data to perform an environmental inventory. Gunnar Westerlund of

⁵²The institute is funded with university, government, and industry contributions.

Volvo was instrumental in the development of EPS. He had a desire and a need to bring scientific, objective analysis into product design decisions. His most recent experience arose from a debate and lack of agreement concerning the use of plastic or metal for a part. Westerlund knew what the designers needed and he helped establish ground rules for the EPS to meet these needs.

Approximately 10 (likely 12) companies—Asea Brown Boveri (ABB), Akzo Nobel, Chemistry, Electrolux, Ericsson, Statoil, STORA Kopparberg, Tetra Pak, and Volvo, among others—cooperated on the EPS development, which included establishing an extensive materials database as well as the model. Their objective was to develop a comprehensive, easy-to-use tool that a designer could use to make quick design trade-offs based on the ecological impacts of product design choices. Two important factors that contributed to the success of the EPS project were support of experienced, senior management on the industrial side (e.g., the Volvo Group Vice President) and knowledgeable scientific researchers. Generally, industry members worked with the scientists to build consensus on the model ground rules and system boundaries. The scientific details were left to the scientists.⁵³

The early design stage was targeted for an analysis tool because, at this stage, high-leverage opportunities can be found, a significant impact on environmental performance can be achieved, cost-effective changes can be made, and the summation of many “little” changes (changes without the specific intent of making a “green” product) can still have a large impact. To ensure that these early decisions were made with the proper information, the methodology had to be as comprehensive as possible. And in order to enable design engineers to use the tool in a practical sense, it had to generate simple results quickly and provide information that is easy to use, because too much information would add confusion. In the early design phases, many different product options are considered and analysts can quickly get overloaded with information. For this

⁵³We repeatedly heard that five individuals spearheaded this effort. The two leading scientists mentioned in our conversations were Sven-Olof Ryding and Bengt Steen. The leading industrialist mentioned was Gunnar Westerlund of Volvo, who recently won an award for his contributions from the King of Sweden. Two others were not identified by name.

reason, EPS aggregates results for all the environmental effects into one number, called an environmental load unit. This approach is somewhat controversial, and the EPS has been criticized by many for aggregating the results on such a broad range of environmental impacts into one number. Again, EPS system developers wanted system transparency as well as straightforward results to balance the needs of product designers. Individual assumptions can be overridden if the design engineer prefers.⁵⁴

The data collection and analysis process for developing EPS was extensive and time-consuming. Many of the existing data were old, in inconsistent formats, etc. The companies spent a lot of time establishing a common database structure. They did this sector-by-sector (iron and steel, forest products, manufacturing, textiles) and then the Environmental Research Institute decided which data to use. The database covers 10 to 12 different environmental effects, such as acidification, global warming, toxics, biodiversity (the most difficult to measure), and is continually being updated. Much of the scientific information in the model is rough, but the system developers' philosophy was to get a top-down structure and worry about the details later.

Methodology

EPS is an integrated system of the various steps in a life-cycle analysis. Active organizations in the LCA field, including SETAC and the International Standardization Organization (ISO), structure LCAs into three components: an inventory analysis, an impact assessment, and improvement analyses (SETAC, 1990, p. xviii; Ryding et al., 1993, pp. 3–4). EPS adds a fourth component—goal definition and scoping.

⁵⁴The British research community prefers to report at a more detailed level and then to let the engineers make the environmental trade-offs. EPS includes environmental priorities within the tool (using valuation) because design engineers are not necessarily experts on environmental issues (such as NO_x and SO_x emissions) and are focused on maintenance and disposal issues. AT&T/Lucent Technologies prefers a set of qualitative matrices that display all the environmental impacts as well as judgments about uncertainty.

- The goal definition and scoping component addresses the explicit reasons for performing the LCA, which can range from comparing products (for external use) to strategic planning (for internal use).
- The inventory analysis is the identification and accounting of environmental effects to include natural resource use and air, water, and soil emissions for a product.
- The impact assessment is the characterization of environmental effects on the environment and human health. It can be quantitative or qualitative and includes three phases: classification of impacts, characterization of emissions and use in the classification selected, and relative valuation of the various impacts (this is the most controversial element of an LCA).
- The improvement analysis component identifies (1) product characteristics, whether they be material use, design, operations, or something else, that offer greatest leverage for improvement and (2) the process for determining how to achieve those gains.

A life-cycle analysis will not necessarily employ all four of these components. What is included depends on the first—the goal of the LCA. All four of these components are included in EPS.

Ground rules were agreed on between industry and scientists and are aligned with principles of sustainability. They have developed the following set of principles for EPS, which are easier to communicate than the mathematical details of the model:

- Be comprehensive, that is, include all environmental effects for the safeguard subject areas. Report results simply, summarized in a common measure (called an environmental load unit).
- Treat all generations and areas of the world equally (use a zero discount rate).
- Employ the precautionary principle to environmental threats (e.g., consider global warming even though the effect has not been proved definitively).
- Provide a baseline as a default scenario to simplify the analysis during design. Adjust it locally as needed to reflect the specific needs of the user.

- Maintain transparency by exposing all assumptions clearly and use linearity wherever possible to maintain simplicity.⁵⁵
- Include uncertainty explicitly; build it up from uncertainty about individual parameters and factors; and display cumulative uncertainty.
- Weight “safeguard” subjects with willingness-to-pay studies to provide valuation of the estimated environmental impacts.

The EPS uses average risk assessment methodologies to relate risk to results, such as human mortality or loss of biodiversity (versus CO₂ emissions or global warming potential), in the five safeguard subjects: biodiversity, human health, production, resources, and aesthetic values. Input parameter sensitivity analyses are performed and these average risks are calculated using Monte Carlo techniques. For example, so many kilograms of SO₂ emissions reduce tree coverage on average by X hectares, which increases human mortality by X percent. Willingness-to-pay is then used to weight the effects in the safeguard subject areas aggregated into an environmental load unit, the model output, so that it would take one ECU (euro, or European currency unit) to reduce the effect by one ELU. Results are reported as environmental load units because monetized values can be both misleading and misused (e.g., analysts may attempt to apply a discount rate to it). Moreover, developers wanted users to realize that there was more behind the numbers than just dollars.

It was important to EPS developers to relate risk to “end points,” because individuals can better relate to and value more-specific outcomes. But this was tricky because all the relationships between materials, the associated processes employed, and the environmental effects must be accounted for. For example, each material and process that contributes to acidification must be identified and then the contribution of acidification to each of the safeguard

⁵⁵Linearity is not consistent with threshold effects or many congestion-style effects common to environmental issues. These can be accommodated by changes in the baseline scenario if the designer knows to do this. The long-term goal is to develop, in effect, an intelligent decision support tool that would take care of such problems automatically. Until then, designer intervention is important. Poisons generally have threshold levels, so if the emissions are below these levels the calculations are not performed. Carcinogens have linear dose-responses.

subject areas must be estimated. In this case, it was estimated that acidification contributes to 15 percent of the biodiversity loss in Sweden. As much science as was available was used to guide these relationships; otherwise either simple relationships or models were developed, or an educated judgment was made. The system developers used global, regional, or local data, when available. Otherwise they used Sweden-based data to represent the world.⁵⁶ The developers hope that advances in scientific knowledge will inform and improve these estimates over time.⁵⁷

Natural resources are valued at the cost of re-creating them or substituting for them if their supply were exhausted. For example, EPS developers have estimated how much it would cost if copper were depleted and had to be extracted from the earth's crust. This would involve mining, crushing, etc., including the expenses for vegetable oil, wood, acid for leaching, and processing, for a total of ECU56 per kilogram. This, and not market prices or forecasts, is the value placed into EPS for the natural resource of copper. This procedure cannot necessarily be used with all metals as they cannot all be reclaimed. Rare-earth minerals are more difficult to deal with than other metals and minerals. The value to future generations of going without a resource that cannot be replaced is what is applied to today's use, because the market has no scarcity value. Sometimes resource exhaustion may take much longer than 100 years (a long time for companies, a short time for science).⁵⁸ EPS is about sustainability, the fundamental goal underlying this model, and so the natural resources are included in this way.

⁵⁶At about this time (starting in 1989), United Nations Environmental Program reports were being published, and they provided useful information.

⁵⁷All input sources are documented in Excel spreadsheet notes. The models use the linear form of average probabilities and apply uncertainty bands to probabilities. Subjective judgments are used to estimate uncertainty bands (for example, factor 10 of log-normal distribution). Uncertainty is introduced in many ways—parameter estimation, exposure pathways, pharmacokinetics, willingness-to-pay, etc.—and includes future regulations. Optimization routines deal with harm, not the willingness to pay.

⁵⁸Eventually everything is regenerative (species come and go, minerals come and go) in the long run. But this time horizon is so much larger than human time scales that costs for living without a resource may be so large that they approach infinity and in effect the resources are depleted.

The various environmental impacts are combined into one number using valuation weights. Not many life-cycle assessments include valuation. Valuation is not universally seen as appropriate for life-cycle assessment. The valuation weights in EPS are based on willingness-to-pay data and are normalized so that the output, an environmental load unit (ELU), is equivalent to one euro (ECU). Willingness-to-pay values were drawn from an inventory of all such studies relevant to global, regional, and local areas where the data were available. EPS developers found it relatively easy to find willingness-to-pay data for health effects and much more difficult to find such data for biodiversity loss and mineral extraction (iron ore or copper ore). The developers' main source for the hard-to-determine biodiversity data were Swedish expenditures on natural spaces and parks (approximately SKr800 million per year) and Norwegian university studies. The developers feel that valuation is an important contribution of EPS. While other LCA models may be stronger on the natural sciences side, EPS provides guidance on weighting or valuing the environmental impacts. EPS developers felt that willingness-to-pay is the only systematic means for weighting various environmental impacts. However, getting reasonably accurate estimates for these values is extremely difficult. Despite these uncertainties, some regulators in Sweden were comfortable with the willingness-to-pay valuation. In part, this is because of the abundance of studies performed in preparation for a new packaging law. These studies were used to calibrate EPS, so now the regulators are comfortable with the system. This was actually one of the areas of agreement between the regulators and industry.

Environmental scenarios are part of the methodology. The baseline is the present situation and today's technologies and practices (e.g., how pollutants or chemicals are currently disposed of and the associated effects). This tool does not forecast the future but is a series of "what if" analyses.

Experience with EPS

Approximately three years after project start, the EPS has been used by most of the companies to varying degrees as a function of their product lines. While all participating companies have used EPS to

some extent, Volvo has been the most active.⁵⁹ Member companies, such as ABB, Electrolux, and the STORA Kopparberg Group, are not using EPS in a way consistent with the guiding principles. For one, they often modify the assumptions regarding valuation, especially of natural resources. This is partially because companies generally view five- to ten-year time horizons as long; while science views 100 years as short. However, the public may pressure companies through regulations, so in the long run companies should be prepared. In addition to the modifications regarding natural resource valuation, companies would like to see EPS report emissions and natural resource use separately. Some separate the results for the safeguard subjects and focus on a particular area. However, EPS combines them as a consequence of its established ground rules. Volvo, the most active EPS user, does not use EPS for all designs. It looks at the various emissions, not just the aggregated ELU. And it uses different baseline scenarios.

Engineers are happy with the system. It is easy to use, and the engineers get a lot of satisfaction contributing to environmentally sound products. While methodologies are more product-specific, the supporting EPS database is easily transferable. This database is available to any entity, including the U.S. DoD. In effect, EPS provides a national materials database. In contrast, such U.S. databases as Franklin and Associates database are commercially developed and owned. The EPS developers have not done a lot to promote EPS and to encourage design engineers and others to use it.

EPS has limited application to regulatory policy, although Volvo used results on automobile recycling to negotiate inclusion of energy recovery. The EPS use of average probabilities and globally relevant data means that it is not particularly applicable to local problems. The use of average probabilities would skew results if, say, the transport mode, exposure pathways, or geography could have dramatic effects on harm done, such as in the case of arsenic. To use EPS for

⁵⁹In contrast, Tetra Pak, a packaging company, did not use it much. This is because Tetra Pak needed greater accuracy than the EPS valuation system provides. It had been doing life-cycle assessments for a while, had its own database, and so was experienced with life-cycle assessments in general. It needed greater visibility into the parameters and had to make trade-offs at a more detailed level than provided by EPS. Tetra Pak and STORA used EPS for a beverage carton.

regulatory policy that addresses local needs, data and load conditions would have to be collected and developed for the unique aspects and environmental impacts of the locality. However, for some global or far-reaching issues, such as ozone, society must set direct limits through regulations, in which case EPS, as is, may be relevant.

Relationship to ISO and Other Governance Structures

There is no straightforward relation between EPS and ISO 14040, because EPS preceded ISO. However, EPS experience has been communicated to the ISO 14040 technical committee. While EPS fits the developing ISO framework, there is a debate on whether or not valuation belongs in an LCA. Clearly, the EPS developers feel that, if valuation is transparent, it is permissible to include in an LCA. There is also no connection between EPS and EMAS, which is oriented toward production facilities' emissions, not product design.

According to its developers, industry views the EPS as useful for only one purpose, making product development more environmentally sound. They do not think that it is suitable for regulatory purposes, which require greater specificity. EPS may be used for eco-labeling programs as long as the uncertainties and inaccuracies are communicated. U.S. industry in general would probably strongly disagree with using LCAs for eco-labeling.

AB VOLVO GOALS AND ACTION PROGRAM

In 1993, Volvo Group Executive Committee implemented the "Environment 95" action program to run to the end of 1995. The program consists of goals for 20 different areas. Progress toward goals is evaluated annually, and progress is summarized. A new program, emphasizing the environmental impact of products, EMS, production processes, and communications will be implemented in 1996.

The 20 goals established in 1993 are listed in Table A.2. See Volvo's 1995 Environmental Report for an assessment of progress toward its goals and more detailed remarks.

Table A.2
Goals of the Volvo "Environment 95" Program

	Goal	Progress ^a (percent)
1	Establish a well-developed environmental organization, with clearly defined line and managerial responsibilities for environmental affairs.	50
2	Establish environmental councils in companies and plants.	75
3	Implement regular training and information programs in environmental affairs for various personnel categories.	75
4	Implement the EPS system of life-cycle assessment as a design aid and decisionmaking instrument at different levels.	25
5	Complete a first round of environmental audits in all production units.	75
6	Establish an environmental communications strategy with the environmental message as a key element.	75
7	Prioritize and seek environmental optimization in industrial processes for energy, volatile organic solvents, water pollution, chemical use, and waste.	75
8	Monitor the environmental performance of suppliers, stipulating environmental policy and auditing conditions in applicable cases.	25
9	Implement a plan where alternative CFCs, halons, 1,1,1-trichloroethane are available. 50% progress on CFCs, 75% on halons, 100% on 1,1,1-trichloroethene.	75
10	Ensure one unit in each truck engine family complies with Euro 2 standards.	100
11	Develop test series of distribution trucks burning natural gas or alcohol.	100
12	Introduce an environmental concept truck for urban delivery applications.	100
13	Ensure that at least one variant per model family in the VCC meets the strictest environmental requirements in the European incentive system.	25
14	Ensure that VAC's small gas turbines have the lowest emission levels on the market.	75
15	Ensure VPC is the first marine engine manufacturer to have five diesels emission-approved for operation on Lake Constance.	100
16	Develop and establish recycling system for vehicle parts and materials in Sweden.	50
17	Publish scrapping manuals for (a) cars and (b) trucks.	(a) 100 ^b (b) 25 ^c

Table A.2—Continued

	Goal	Progress ^a (percent)
18	Participate in demonstration projects of both cars and goods delivery truck in built-up urban areas.	100
19	Develop navigation, positioning, and communications systems for installation in demonstration vehicles and for commercial sale.	100
20	To be, and considered, one of the most environmentally aware companies in the transport sector.	75

^aApproximate degree of progress toward goal. 100 percent indicates that the goal has been completely realized.

^bFrom 1975.

^cFrom 1978.

Appendix B

HEWLETT-PACKARD CASE STUDY: PRODUCT STEWARDSHIP: GREEN COMPUTES

This case study is based on several papers written by Hewlett-Packard's personnel over the years that product stewardship was in development. Information in these papers was augmented with focused personal interviews of select HP personnel. Note, case studies by their nature are snapshots of an organization. Today, the details of the program and the perspective of participants are likely to be somewhat different from the ideas presented here.

HEWLETT-PACKARD IS A MULTINATIONAL CORPORATION

Hewlett-Packard manufactures products and systems for computation, communication, and test and measurement. The three major business sectors of the corporation are the Computer Organization, the Test and Measurement Organization, and the Measurement Systems Organization. These sectors are broken down into groups, businesses, and product-line divisions, which are quite fluid and independent entities. Revenues for the company as a whole in 1996 were \$38.4 billion¹ and reached \$42.9 billion in 1997, according to Hewlett-Packard's web site. Some of this equipment, such as computers and printers, is produced in large volumes, while others, such as test and measurement equipment, are not. Manufacturing facilities are located worldwide—in North America, South America, Europe, Australia, and Asia. In 1995, more than half of HP's products

¹HP 1996 Annual Report, Financial Highlights, <http://www.hp.com/financials/96annrep/Financials/Highlights>.

sold were designs that were two years old or less.² In 1997, more than 123,000 employees worked for HP in 120 countries.

Environmentally conscious product design, or design-for-environment, is called product stewardship at HP. It is

the philosophy and practice of designing products and their associated accessories and processes to prevent/minimize adverse health, safety, and ecological impacts throughout their life cycle. (Bast, 1996, p. 42.)

Differences in product and market characteristics influence the implementation of product stewardship between the various business units that constitute the corporation. HP corporate managers have not implemented product stewardship with the expectation that all product managers will (or should) be equally responsive to the program.

The HP product stewardship program is still very new. The first HP business to begin design-for-environment was the Computer Products Organization. This program was initiated in 1992 and was extended corporatewide one year later. According to the Corporate Product Stewardship Manager, the strategy for product stewardship implementation at HP is to develop the product stewardship process, provide tools and information, and then rely on the merits of the program and innovative individuals who champion its merits to drive implementation (Bast, 1996b). Table B.1 represents a time line of product stewardship developments and shows how HP has been laying in the procedures, tools, and information to get the program started since 1992.

SEVERAL FACTORS INFLUENCE DESIGN-FOR-ENVIRONMENT AT HEWLETT-PACKARD

Regulatory and market forces, environmental policy, and corporate culture and values influence how product stewardship is imple-

²HP 1996 *Annual Report*, Financial Highlights, <http://www.hp.com/financials/96annrep/Financials/Highlights>.

Table B.1
HP Corporate Product Stewardship Time Lines

Year	Milestone
1979	Environmental audits begun at HP
1992	Environmental policy revised to include product design
1992	Computer Products Organization product stewardship program begun
1993	Environmental Management Steering Committee established
1993	Product stewardship program extended to all product lines corporatewide
1993	Product design guidelines package formalized
1993	Product metrics developed
1994	Fountainhead database developed
1995	Self-assessment process tested
1996	Self-assessment process implemented worldwide

mented at HP. Specifically, the organizational structures and procedures used to consider environmental issues in design are shaped and driven by these three broad areas. Taken together, these areas can be considered as elements of the overarching factor—business processes and contexts—that drives design-for-environment at HP.

Regulatory and Market Forces

Motivation or drivers for the Hewlett-Packard product stewardship program are a mix of regulatory and market forces, including customer preferences and competitor actions. In particular, German packaging takeback legislation enacted in 1993 drove manufacturers to consider packaging volume. Proposed legislation extends manufacturer responsibility to the entire product, and will require original equipment manufacturers (OEMs) to take back products after their useful life.

In addition to legislation, the second significant set of motivators in the HP product stewardship program consists of two eco-label programs, the German Blue Angel Program and the U.S. EPA Energy Star Program. Product standards in these two programs influence HP product design. The German Blue Angel Program is considered one of the most mature eco-labeling programs. Similarly, according to a survey performed by the German Fraunhofer Institute, 67 percent of the Germans surveyed said that they considered the Blue Angel label when making a purchase. Blue Angel criteria for personal computers

were introduced in 1994, and HP has qualified several of their products under this label (Dirksen, 1996, p. 302). Under the EPA's Energy Star program, a manufacturer may use the Energy Star label on product and marketing literature if they meet product criteria for energy use. This voluntary program was backed up with a presidential executive order requiring federal agencies to purchase only computer and printer products that met these criteria.³

Third, HP plans to use product stewardship to meet market demand more generally. That is, it intends to meet and anticipate customer preferences for a product's environmental attributes. For some products, the HP marketing organization has detected customer preferences for environmentally superior products (Korpalski, 1994, p. 207).

These drivers affect the HP products to different degrees, so HP corporate has focused attention strategically. Their strategic attention has been placed on the products produced in higher volumes, as well as those expected to grow because of its concern regarding the generation of mass. For instance, computer products are produced in high volumes and any seemingly minor change to product design can have a large impact on the environment. In contrast, test and measurement devices are produced in smaller volumes. While improvements could be made, HP has decided to focus implementation on the products with higher leverage. This mix of regulatory and market forces around the world has influenced members of the company to consider proactively these and impending forces in product design as a means of finding solutions that can meet both environmental and business objectives.

HP Environmental Policy

HP's own environmental policy is a second factor that influences design-for-environment implementation. The environmental policy is the overarching mission statement for all environmental activities in the company, and it establishes a framework for thinking about the issue. The HP environmental policy was revised in 1992 to

³Requiring the purchase of environmentally favorable products is often called affirmative procurement (Bast, undated, p. 2).

include a corporate intent to design and manufacture environmentally sound products and services, and it now reads:

To provide products and services that are environmentally sound throughout their life cycle and to conduct business operations [worldwide] in an environmentally responsible manner. (Hewlett-Packard, 1993.)

Because HP sells products and has manufacturing operations worldwide, product stewardship is very important. Unlike manufacturing operations, which need only worry about local regulations and laws, product-related environmental attributes are influenced by regulations and laws in all markets. For HP, that means its products must satisfy regulations and standards promulgated worldwide. The corporate intent to design and manufacture environmentally sound products, in worldwide markets with varying standards and legislative requirements, while additionally fulfilling or exceeding customer preferences and competitor actions, is extremely challenging.

HP seeks to meet these challenges by integrating product stewardship into all normal business processes—R&D, marketing, manufacturing, procurement, distribution, and especially design. HP hopes that, by utilizing the creativity and expertise of its product designers when product attributes are relatively easy to change, it can effectively meet these challenges over the long term. HP seeks to find more environmentally responsible solutions through design rather than to have others in the company dictate responses through various means (Korpalski, 1994, p. 207). Furthermore, consideration of these issues in the design phase is a means of positioning products to meet or exceed anticipated future requirements (Bast, 1997b).

Included with the environmental policy statement are 11 fairly specific guiding principles. Several of the principles particularly relevant to product stewardship are listed below. Especially key aspects are in *italics*.

- Ensure that environmental policies, programs, and performance standards are an *integral* part of our planning and decision-making process.

- Regard sound environmental management as an integral part of our total quality commitment and to apply these principles and practice of *continuous improvement* accordingly.
- *Design* and construct our facilities to minimize waste generation, and to promote energy efficiency and ecosystem protection.
- *Design* our products and services and their associated manufacturing and distribution processes to be safe in their operation, minimize use of hazardous materials, make efficient use of energy and other resources, and enable recycling and reuse throughout their manufacture, distribution, and operation.
- Ensure that our *suppliers* support our Environmental Management Policy and encourage them to adopt similar principles.

The rest of the principles address reduction of chemical and solid waste generation, remediation activities, openness to all stakeholder interests, employee involvement, and active engagement in public policy discussions. These principles are employed as product stewards make connections to standard HP business processes. Note that the key aspects of the environmental policy and principles relevant for product stewardship implementation are the life-cycle perspective, integration of EH&S with standard planning and decision-making processes, the link to quality and the desire for continuous improvement, and supplier involvement (Bast, 1997b). All of these are used to implement design-for-environment in the context of business processes. The most important factor, however, is customer interests and expectations.

HP Corporate Values and Culture

A third factor that influences design-for-environment implementation is HP's corporate values and culture, which have included concern for the local community for some time. In 1957, Hewlett-Packard established corporate objectives that call for the company to be an asset to the nation and to each community within which the company operates. Dealing with environmental, health, and safety issues is one element of good corporate citizenship (Hewlett-Packard, 1994, p. 1). Internally, corporate culture is characterized as decentralized and cooperative. Corporate values, described as "the HP way," refer to cooperation with co-workers, which is a valued

employee asset. Corporate values are best described in the words of the company co-founder, David Packard.

I want to discuss why a company exists in the first place. In other words, why are we here? I think many people assume, wrongly, that a company exists simply to make money. While this is an important result of a company's existence, we have to go deeper and find the real reasons for our being. As we investigate this, we inevitably come to the conclusion that a group of people get together and exist as an institution that we call a company so they are able to accomplish something collectively that they could not accomplish separately—they make a contribution to society, a phrase which sounds trite but is fundamental. . . . You can look around [in the business world] and still see people who are interested in money and nothing else, but the underlying drives come largely from a desire to do something else—to make a product—to give a service—generally to do something which is of value. So with that in mind, let us discuss why the Hewlett-Packard Company exists. . . . The real reason for our existence is that we provide something which is unique [that makes a contribution]. (Collins and Porras, 1994, p. 56.)

In summary, three categories contribute to implementation of design-for-environment at HP. The first includes the regulatory and market forces that motivate the specific analyses and investments made during design and that can vary considerably for the individual products designed and produced by HP. The environmental management policy emphasizes integration of environmental, health, and safety with general business practices, a life-cycle perspective, continuous improvement, and supplier involvement. Customer interests and expectations are the primary driver of what the product stewards do. Finally, the decentralized corporate structure and core values of good citizenship, community involvement, and cooperative behavior among staff shape the activities used to implement product stewardship. All of these factors affect the specific organizational structures and processes used to promote HP's product stewardship programs.

AN EXECUTIVE STEERING COMMITTEE SPONSORS A DECENTRALIZED PRODUCT STEWARDSHIP ORGANIZATION

The corporate office orchestrates and supports the product stewardship program, but responsible individuals in each of the businesses and product lines make it happen.

Organizationally the program is decentralized and integrated with design and other business activities, such as procurement and marketing. Networks are created among the corporate, business, and product-line product stewards to develop and implement the program. These networks, informal and formal, are critical to implementation. The corporate product steward has worked, and continues to work, with business product stewards and product-line stewards to establish a process for product stewardship consistent with their corporate culture and policies. They have also worked together to develop the tools and information required for success and to make these available corporatwide.

The overarching coordinating body for environmental, health, and safety issues at HP is the HP Environmental Management Steering Committee. Established in 1993, this committee is responsible for developing the companywide environmental policy and strategy in general. Executives representing all HP groups or businesses are on the committee. At HP, these executives are at the general manager level, which is equivalent to a vice president of a strategic business unit for a typical major corporation. Because the HP sectors, groups, and businesses are so diverse, the executives that sit on the committee come from a variety of business functions. Some groups may be represented by R&D, manufacturing, or personnel. Generally, the group representative to the committee is from a functional area, which, for that group, coordinates across all group functions. The variety of business functions present on the committee is an asset to integrating environmental, health, and safety issues into these processes. The HP Environmental Management Steering Committee sponsors the corporate-level Product Stewardship Council, which is a key part of design-for-environment implementation because it develops the tools and information to aid all the product-line stewards companywide. This sponsorship gives the Product Stewardship Council clout.

The Product Stewardship Council develops corporate processes, procedures, and organizational principles for product stewardship specifically. This council identifies and develops corporatewide projects to advance and support the product stewards. Business-level or group-level product stewards and the corporate coordinator for product stewardship sit on the council. Members represent such business functions as material procurement, quality, public affairs, legal, electronic assembly development, packaging engineering, and computer systems personnel. The corporate product stewardship organization itself is lean, so different projects are staffed by individuals from across the corporation to draw on expertise as appropriate to the project.

Therefore, at the corporate level, two bodies contribute to the product stewardship program. The HP Environmental Management Steering Committee develops overarching environmental, health, and safety policy and procedures for environmental management in general. A high-level committee sponsors the product stewardship activity. The Product Stewardship Council aids the individual product stewards with information, policies, and processes specific to product stewardship or design-for-environment, ensuring that these are consistent and integrated with other business practices.

NETWORKING IS A KEY COMPONENT OF PRODUCT STEWARDSHIP

Each HP business and product line has designated product stewards so that corporatewide there are between 75 and 100 throughout the world. This organizational structure was begun and tested in the Computer Products Organization in 1992. Then, in 1993, each of the other HP businesses was asked to designate a product steward to champion activities at the business level (which may be equivalent to sector, group, or a business, depending on the breadth and depth of the entity's product lines). In turn, the business product stewards identified product-line product stewards to champion efforts. For example, the Computer Products Organization has a product stew-

ard for the business overall, as well as 19 product stewards for each of its product lines.⁴

The business-level product steward works with each of the product-line stewards and the Corporate Product Stewardship Council to establish the policies and tools necessary for implementation for the business overall. The business-level product stewards perform several important functions. First, they communicate with all parts of the company, such as the marketing and procurement organizations, to gather information as well as raise awareness about environmental issues. They also track, assess, and relate relevant market and legislative forces to the business's product portfolio. And they increase the awareness of business staff on these market and legislative forces as well as the benefits of considering them early—for example, in design. Business-level product stewards are also key players in the development and implementation of procedures that will improve the treatment of environmental issues in procurement, design, etc. Finally, they develop and employ such tools as product design guidelines and metrics.

For each product line, responsible stewards are the critical link between environmental issues and the design team. Furthermore, their knowledge of the product, market, and business processes issues is extremely important to integrating environmental issues in these contexts. The stewards provide information to the design team on

- environmental legislation
- customer interests
- eco-labels
- competitors' actions.

These stewards are the initiators and facilitators of discussions on environmental issues with the product-line manager and the design team. Ultimately, the product-line manager and the design team decide which criteria are feasible and desirable to meet.

⁴These product lines include personal computers, such as the HP Vectra; printers; servers; monitors; scanners; faxes; and multifunction devices, such as printer/faxes.

Product stewards at both the business and product-line level are not necessarily environmental experts. Depending on the division, a more appropriate choice may be an R&D expert, a marketing expert, or a manufacturing expert. R&D, marketing, and manufacturing, the "triad" as they are called, are the three functional areas predominantly relevant to product stewardship at HP. However, this may differ for each product line. In Grenoble, for example, the steward is a customer service expert.

HP has found that some champions or stewards are more influential than others. Part of this is because the product steward job description is evolving and it may take a couple of iterations before the right person is matched to the job. Experience to date suggests that it takes the right mix of salesmanship, enthusiasm, aggressiveness, and influence. Dialogue and a thorough understanding of the strategic business issues are the key elements in this process. The product steward must know the relevant functional issues and use these, with general business objectives, including customer preferences, to drive environmental actions. It is difficult to measure a product champion's effectiveness, because HP does not have good methods to relate product steward actions to results (e.g., the number of additional units that were sold because of environmental attributes or an eco-label). In some divisions the product stewards are full-time, and in others they are part-time.

To help jump-start the stewardship program, the product stewards met for two days every six months during the first three years of the program. These meetings were to discuss issues of mutual concern. Some of this involved "show and tell" to exchange lessons learned. For example, a product steward from one product line described how they engaged the design team. On other occasions proposals for corporate product stewardship policies (not division policy) were discussed. For example, at one of these meetings product stewards decided that a good way to engage business managers in the stewardship program was through a unit self-assessment. Details of the procedure were discussed and fleshed out at these meetings. On another occasion, corporate strategy regarding environmental criteria for suppliers was discussed. Now that the product stewardship program has been jump-started, these formal meetings are less frequent. Information among product stewards is exchanged through a

combination of electronic mail, audioconferencing, and a corporate worldwide database described below.

To summarize, organizationally, HP has placed environmental stewards, responsible for incorporating environmental issues into design decisions and processes, within each product line. They are the critical link toward integrating environmental issues with other business issues, and their market knowledge and business expertise is crucial. These stewards are guided and helped both by the business and the corporate level. The decentralized structure is quite consistent with HP organization in general. Initially, product stewards met twice per year to share lessons learned and to develop standardized policies and procedures. According to the corporate product stewardship manager, these meetings were very useful in jump-starting the program (Bast, 1997a). Frequent communication between the product stewards across the company as well as between the stewards and designers is crucial. Because the product steward job is still evolving, specific skills have not been explicitly enumerated. However, a strong ability to communicate and understand both the division or product-line strategy and the design process is critical. Individuals with R&D, marketing, or manufacturing experience most often have the requisite knowledge of market, product, and business issues.

INFORMATION GUIDES PRODUCT STEWARDS

Because HP is so decentralized, and because the corporate culture is cooperative rather than hierarchical or rigid, one of the key facilitators to design-for-environment at HP is information. The parallel organization for all the sectors and businesses, with clearly identified product stewards, aids information flow. Information is also contained and shared in a database called Fountainhead, which is available corporatewide. Developed by the corporate Product Stewardship Council in 1994, this is the primary formal vehicle for information exchange among the corporate, the division, and the product-line stewards, numbering between 75 and 100 individuals worldwide. Included in the database is information on worldwide environmental trends both market and regulatory. Also included in the database are corporate environmental policy and principles, product steward points of contact, design guidelines, suggested

metrics, benchmarking data, and meeting notes. Figure B.1 shows the file structure in the Fountainhead database.

As noted in the figure, the “General Information” area contains information on product stewardship contacts, issue leads, design-for-environment guidelines (created by the corporate council), minutes from product stewardship meetings, and information on best practices. “Issues” includes corporatewide fact sheets on such issues as ozone depleting substances and energy. “Topics” contains more technical information for the headings shown in the figure (batteries, chemicals, etc.). Finally, the “What’s New” area contains information updated within the last month. The other areas, “Geographic Regions” and “Business Groups,” contain information specific to those areas, including business group metrics and design criteria (Holbrook, 1995, pp. 301–304). All sorts of information is collected from industry associations, standards organizations, government agencies, consultants, HP employees, and others and assessed before it is included in the Fountainhead database. A crucial step is the evaluation of this information and its relation to HP businesses.

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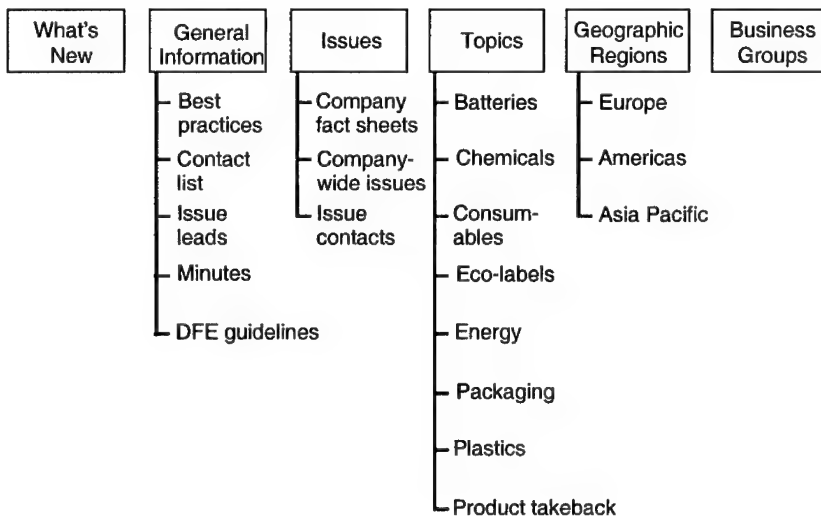


Figure B.1—Fountainhead Database Structure

If appropriate, recommendations on compliance strategy or corporate position are also included. It has been placed on a standard HP information system, which is currently available to 55,000 users.

GUIDELINES AND METRICS ARE USED TO INTEGRATE ENVIRONMENTAL LIFE-CYCLE ISSUES INTO DESIGN PROCESSES

Generally, HP products turn over quite rapidly. Product design life averages 12 to 18 months and in some cases may be less than 12. PCs and a few printers are especially affected by market forces. All product performance criteria are linked to the financial system. In some cases, design teams know their margins down to the penny. Generally, the bottom line is that they cannot increase their purchase price. So product design decisions must be pragmatic and consider customer preferences.

Armed with strategic market and regulatory information from the Fountainhead database, support from the organizational links across the division as well as the company, and their own understanding of the specific product market and business issues, the product-line stewards integrate environmental issues into the design process with a couple of tools—design guidelines and product metrics. Again, the process of developing and applying these tools is somewhat decentralized.

Corporate design guidelines were developed by the Product Stewardship Council, select business-level product stewards, and personnel from manufacturing, procurement, marketing, alternative sourcing and recycling, and R&D. In order to develop these guidelines, the staff did not perform a full-blown life-cycle analysis of all environmental effects. Rather, they worked through the product value chain from R&D through disposal and performed a gross assessment of the environmental effects.

Using the results of this gross-level analysis they developed a set of generic design-for-environment guidelines that can be applied as appropriate to all HP products. These guidelines are broad and generic enough so that, irrespective of the specific product, they will help position the product better on environmental issues. Guidelines cover the areas of product use, packaging, consumables

and supplies, manufacturing processes, and end-of-life strategy. They include such preferences as reduce mass, eliminate hazardous materials, and reduce the number of components. Some of the guidelines were easier to develop because of the company's experience recycling and reusing parts in their Roseville, California, and Grenoble recovery facilities.⁵ The guidelines have been revised once and as a result are more detailed. Once the guidelines were created they were spread to the product stewards worldwide through the Fountainhead database.

In addition to the "dos and don'ts" design guidelines, more specific product metrics were also developed by a cross-functional team in late 1993. Several ground rules for metrics were established at this time.

- Metrics should be simple and easy to apply.
- Metrics should focus on strategic issues (those that regulations, standards, or the customer will require) and should incorporate knowledge gained from the field (particularly recovery centers).
- Product designers should have the ability to influence the metrics.
- Metrics represent a starting point for environmental improvement strategies and do not reflect a full-blown life-cycle analysis.

The full metric set is shown in Table B.2. It should be noted that not all of HP products are evaluated and measured for environmental performance improvements. Product teams and product-line stew-

⁵HP began a recycling facility in Roseville in the late 1980s as an alternative way to generate parts for servicing (rather than tie up manufacturing facilities to generate these parts). This center was not originally developed for environmental reasons, although there is an obvious benefit. The center is profitable in part because it recycles or reuses *select* parts. If it tried to recycle or reuse all parts, it would not be profitable. In some cases, it might make sense to reuse parts or extend the design life or reuse components or scrap materials. The economics of recycling depends on the volume. In 1995 HP recycled or reused 1.25 million pounds of plastic per month. Over the year 1.1 million pounds from the general ABS recycled plastics market were recycled in the outer casing of the HP 850 Deskjet printer. The benefits of this experience help product stewards understand the ultimate fate of materials and recycling costs.

Table B.2
HP Corporate Stewardship Metrics

Category	Metrics	Applications
Materials conservation and waste reduction	Mass or weight	Products
	Percentage reused	Consumables
	Percentage recycled	Packaging
Energy efficiency		Learning products
	Normal operating mode watts	Products
	Sleep-mode or power-down watts	
Manufacturing Emissions	Off-mode watts	
	SARA 313 emissions	Processes
	Hazardous waste generated	Office Waste
	Hazardous waste reused/recycled	
	Site solid waste generated	
Design-for-Environment	Site solid waste reused/recycled	
	Variety or number of materials	Products
	Plastics marked	Consumables
	Recycled material content	Packaging
	Materials requiring special handling	Learning products

SOURCES: Korpalski, 1994, p. 209, and 1996, p. 40.

ards have considerable latitude in determining not only which products should be assessed in which years, but also which metrics to apply and what values or goals to establish.

Business-level and product-line product stewards then combine corporate guidelines, market forces identified in the Fountainhead database, and knowledge of their own product and market situation to work with the product manager and design team to develop specific product metrics and goals. An important part of the product-line steward's role is to integrate all this information, to select the metrics relevant to the product for which they are responsible, and to develop goals in cooperation with the product-line manager and team. Thus, the product-line stewards work with the design team to apply the design criteria developed at the corporate level to the particular product. The design team and product manager then either set specific goals for these metrics (e.g., a specific mass target of 15 kilograms) or select a product to serve as a baseline and to measure

improvement against the attributes of this product (e.g., decrease mass by 45 percent from the baseline).

Several elements of the guidelines, metrics, baseline, and goal selection are key. First, product stewards think about environmental issues strategically. They focus on the major environmental issues and their drivers. Information on market forces and legislation has been synthesized to develop general product guidelines to be applied to all HP products. This information is continually updated. Product stewards then work with product managers and designers to incorporate corporate guidelines, market forces identified in the Fountainhead database, and knowledge of their own product and market situation to develop specific product metrics. Specific goals against these metrics are determined by the product managers and designers with the help of the product steward.

SELF-ASSESSMENT DRIVES IMPROVEMENT

One of the last elements of the product stewardship program is the self-assessment process. The aim of the self-assessment is to improve business managers' awareness regarding environmental issues and to capture their attention on the merits of the product stewardship program. This awareness then should lead to improvement in environmental management generally and product stewardship specifically. Only if managers can realize these benefits will the program succeed in the long run.

Self-assessments were developed by the Product Stewardship Council to help product-line and business managers evaluate their programs. The self-assessment process was initiated in 1995 and was sponsored by the CEO of HP. Now the HP corporate product steward and council believe the process is complete.

These assessments are seen as a method to engage business managers through their self-evaluation of their product stewardship program. They are not intended to serve an audit function but are intended as a means for division management to drive its program. Evaluation is performed through a structured process that involves division or product-line stewards as well as relevant functional managers.

The meat of the assessment is a series of TQM systems questions that the product steward asks of these senior managers. In other words, they are provocative questions that are action-oriented, not answer-oriented. The concept is that if a manager has no answer to these questions, then the managers probably do not have a comprehensive process in place. The questions cover the broad areas of market knowledge (including customer expectations, the implications of voluntary standards to each product line, and competitor actions) as well as management processes (including business product steward links to corporate and other businesses, an internal management sponsor, business- or product-specific design guidelines, supplier evaluations, and mechanisms to ensure internal awareness and communication of product stewardship principles). The following are examples of these questions:

- Who is the management sponsor to the product stewardship program?
- Does the sponsor have a customer tracking system in place to understand customer needs and expectations?
- Does the sponsor have a legislative tracking system in place?
- Does the sponsor know competitors' positions?
- Are environmental issues incorporated into the supplier selection process?
- Are product guidelines available to all product lines?

These are general questions recommended for self-assessments. Some HP businesses have developed these further.

As a result of this self-assessment, action items may be generated, and progress can then be tracked by the business itself from year to year. At some point the Product Stewardship Council may initiate another round or issue a reminder to the businesses to perform self-assessments. Feedback from the 1995 self-assessments shows clearly that some managers are aware of market forces on environmental issues. As a result of these assessments, the Product Stewardship Council will put more benchmarking detail and questionnaires in the Fountainhead database. Higher-level background information on legislation and eco-labels was also requested to help guide division

strategy. Early feedback also shows that these self-assessments helped elevate awareness about the purpose and benefits of the product stewardship program. Again, HP product stewards recognize that the program will not succeed by mandate. It will only succeed and survive if product managers and others see the benefits.

THE PROGRAM IS COMPREHENSIVE—SUPPLIERS ARE ENCOURAGED, TOO

The HP environmental management policy specifically states that suppliers will support HP's environmental management system and be encouraged to develop their own environmental management systems similar to HP's. Since HP's suppliers operate worldwide, in countries with less stringent enforcement of environmental regulations than in the United States, HP's basic approach to suppliers is to encourage and inform them. In particular, HP advises its suppliers on environmental market forces. Although each HP product line (of which there are 75 to 100) has hundreds of suppliers, there are only 200 major suppliers corporatewide. These suppliers are called strategic suppliers, and HP purchases large volumes from them. HP requests more input on these suppliers' environmental management activities.

In addition, the Product Stewardship Council has developed a set of source selection criteria for the suppliers (in 1992–1993). The environmental criteria are included with other supplier criteria in the categories of technology, quality, responsiveness, delivery, cost, and the environment (TQRDC-E). This is a standard HP supplier evaluation process that continues through contract execution. During source selection, suppliers are rated against these criteria. For the environment category, this rating process is somewhat subjective. Generally, HP divisions and purchasing agents want to see an environmental policy that fits the supplier's corporate culture, complies with its country's laws, saves money, and yields competitive advantage. If these conditions are met, then HP hopes the obvious advantages would provide enough incentive to suppliers to comply, because HP does not feel that it has strong control over its suppliers for the most part. HP is reluctant to audit its suppliers because, in its view, that would be micromanaging, and HP does not have that much power over an individual supplier. The only way HP can

enforce the criteria is through the procurement process. To date, no supplier has been turned away because of an unacceptable environmental management system.

There are two levels of supplier criteria: corporate criteria and product-specific criteria. At the corporate level, in order for a criterion to be included, it must satisfy two conditions. First, the criterion has to be of concern globally. Second, the criterion has to be vetted with suppliers before it is included in the source selection process. The specific environmental corporate criteria, or "E criteria," are as follows:

- Existence of an environmental policy supported by top management. HP suggests that the policy cover manufacturing processes, materials and labels, source reduction, power consumption, reuse and recycle, packaging, and disposal.
- An implementation plan with metrics tied to the supplier's environmental policy.
- No use of ozone-depleting substances.

Supplier performance against these criteria is then evaluated and compared to that of other suppliers of the same commodity. These results are included in the overall supplier performance rating that covers TQRDC-E.

Effective relations with suppliers are an important factor in implementation. HP has found that to achieve environmental goals, there must be cooperation and open dialogue between parties. Effective relations are based on mutual trust and long-term commitments. Joint problem-solving and goal-setting between HP and the suppliers are much more effective in improving environmental outcomes than mandates or other approaches are. The key to success is to work as a team toward environmental ends.

LESSONS LEARNED AFTER FOUR YEARS OF IMPLEMENTATION

Based on HP's recent experience implementing design-for-environment, the HP corporate product steward listed several lessons learned in interviews.

- *Be strategic about the products selected for environmental product stewardship.* Focus on products that really drive environmental performance. Because HP is concerned about generation of mass, it focuses on products with high production volumes. Regulations, customer interests, and eco-labels provide the strategic environmental focus for HP product lines.
- Implement product stewardship in *small evolutionary steps* and *look for breakthroughs*. Do not try to do everything at once.
- Focus management attention on the early adopters and *share this information* with others. For HP, the corporate culture of community and collegiality is important in diffusion of this program. Be flexible and open to change. Dynamic and fluid organizations should plan to adapt the program and product steward personnel during implementation.
- Several activities are associated with the start-up of a product stewardship program. Intensive networking of individuals is important. Once the program is in place, however, and the benefits to the business's bottom lines are evident, it will survive on its own merit. In the end, *corporate has less influence than the product-line personnel on the effectiveness of the program*.
- Environmental issues *must be placed in the business paradigm* so managers can understand and act. Environmental activities that are pursued outside of this context will fail. HP is pushing resource efficiency to drive innovation on environmental matters. Pollution prevention projects are viewed like any other—as a quality issue. While HP does not have explicit financial criteria for pollution prevention projects, experience with compliance and waste disposal activities has given it enough management experience to select proper pollution prevention investments. And, as with new product development, investments are made strategically in manufacturing as well. HP ranks the products and associated chemicals and processes that are likely to experience sales growth in the future and focuses attention here. It is also effective to focus attention on expanding processes and chemicals because *it is cost-effective to incorporate pollution prevention investments while making other new investments in plant and equipment*.

- Industrial ecology is a broader long-term vision that guides strategy. Industrial ecology deals with the fundamental issue of societal needs and wants, products, and the environment. *Out-of-the-box thinking is necessary to analyze the fundamental function demanded by customers and then to think of ways to fulfill this want with products or services with smaller environmental footprints.* For DoD, the environmental security people could work within department planning processes to explore how to meet national security objectives in a way that lessens the environmental footprint either through longer weapon system lifetimes or various upgrades, etc. Pragmatically this can be approached as minimizing the investment required to meet national security objectives.

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